METAL CONTENTS IN SOIL SEDIMENTS AND ASSOCIATED WATER IN SOME RIVER BASINS OF WESTERN UTTAR PRADESH

ABSTRACT

THESIS SUBMITTED FOR THE DEGREE OF

Doctor of Philosophy

IN

GEOLOGY

BY

Abdul Wahid Israili

M. Sc. (Alig.)

FACULTY OF SCIENCE
DEPARTMENT OF GEOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH

1986

ABSTRACT

The area, under study, occupies the upper Ganga-Yamuna doab of Central alluvial plain comprising the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr of Western Uttar Pradesh. The objectives of the present study have been to comprehend the major cation and trace metal levels in surface and subsurface water bodies and associated soil sediments in an area which is agriculturally very rich and is one of the fast developing industrial regions of India. The terrain has the best groundwater reservoirs of the world, where groundwater occurs under water table, perched and under confined conditions.

The excessive consumption of various fertilizers and pesticides in agriculture, rapidly increasing industrialization and urbanization with more sewage sludge disposal and other man-made activities discharges of indiscriminate waste effluents are some of the common pollution sources in the region resulting in introduction of various toxic trace metals and high levels of nitrate and major cations into soil sediments, surface and subsurface water bodies of the study area. The most serious problem of groundwater pollution in the area is due to dumping of industrial wastes because once the metals sorbed in the soil, they could not be removed by rain water, and leached out to the shallow water table aquifers mostly composed of alluvial formation of the Ganga basin.

Results of present study reveals that the average concentration of Na, K, Ca and Mg in river waters, groundwaters and associated soil sediments are well within the permissible limits as recommended by ISI, ICMR, WHO and USGS to potable water, irrigation water and soil sediments, but concentration of Ca and Mg in districts of Meerut, Saharanpur and Bulandshahr appears to be quite high than the recommended permissible limits. The abnormally high values of Ca and Mg in river water, groundwater and associated soil sediments may be attributed to the presence of numerous sugar factories and excessive use of Ca-fertilizers, return irrigation flows, waste effluents of paper and textile mills and large number of chemical manufacturing industries, clay concretions rich in Mg, abundance of carbonate minerals and kankar, etc. In general quality of groundwater is not unifrom in the region. Occurrence of saline and alkaline pockets in between fresh water bodies is frequently reported at several places in the study area. Water surveyed do not constitute any significant potential danger due to major cation pollution in the region.

The major water and soil pollution problem in the region is mainly due to highly toxic trace metals which are being discharged as wastes from various industries and indiscriminate disposal of sewage-sullage, agricultural wastes, etc. Analytical results of trace metals namely, Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr and Cd in various soil sediments and associated water bodies

of the area, reveal that the levels of Cu, Zn, Co, Pb and Cd are well within the permissible limits as recommended by various organisations namely, FWPCF and Ayers and Branson, ICMR, ISI, AWWA, WHO, USEPA, EEC, etc. but concentrations of Cr, Fe, Mn, and Ni exceed much above the recommended values in both waters and soil sediments of the districts of Meerut, Ghaziabad and Saharanpur. These metals and their compounds are extensively used in various industrial processes and simultaneously untreated and toxic metals contained industrial waste effluents directly discharged into the rivers through open drains and sewage pipes and on the land surface nearer to the vicinity of these industries. The possibility of adsorption and settlement of these trace metals by soil sediments with their subsequent leaching down to saturated zone, resulted in their high concentration in subsurface water bodies of the region. Respiratory illness and neurologic disorders are common symptoms due to higher Mn uptake commonly reported in district Saharanpur of the study area. The symptoms of Cd poisoning such as vomitting, abdominal cramps and headache are common among the human beings in the districts of Meerut and Ghaziabad.

Keeping all the factors into account, the author is of the opinion that periodic geochemical study of various trace metals and cations in soil sediments and associated surface and subsurface water bodies of this region is of prime importance in order to prevent and minimise the forthcoming

pollutional hazards in the area studied. Disposal of wastes be done at proper sites after taking into account all the deleterious effects of the various contents in these wastes (municipal, industrial or agricultural). Proper crop rotation practices and managing the land application system be encouraged in order to alleviate the environmental hazards, maintenance of soil productivity and its assimilation power. The strict enforcement of environmental protection laws be made with deterrent punishment as provided in the Environment Protection Act of May, 1986 as passed by the Parliament. Micro-level planning for best land application practices be done before any project is formulated/sanctioned for the overall achievement of best results without endangering the environment of region.

METAL CONTENTS IN SOIL SEDIMENTS AND ASSOCIATED WATER IN SOME RIVER BASINS OF WESTERN UTTAR PRADESH

THESIS SUBMITTED FOR THE DEGREE OF

Doctor of Philosophy

IN

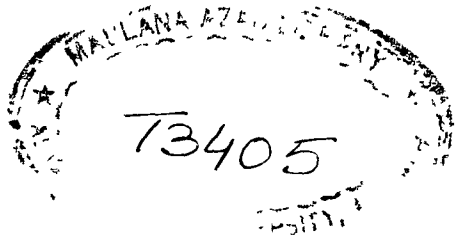
GEOLOGY

BY

Abdul Wahid Israili
M. Sc. (Alig.)

FACULTY OF SCIENCE
DEPARTMENT OF GEOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH

1986



Department of Geology
Aligarh Muslim University

Dr. Sajjad Husain Israili
M. Sc., Ph. D., D. Sc. (Envir.Geol.)
I.A.S. (Netherlands); I.A.G.C. (Praha)
Dip G. W. & Engg. Geol. (Roorkee)
Dip. Comp. Appl. Geol. (I.I.T., Kharagpur)

ENVIRONMENTAL GEOLOGY LAB.
ALIGARH-202001 (India)

Dated 27. 6. 1986

It is to certify that Mr. Abdul Wahid Israili has completed his research assignment entitled, "Metal Contents in Soil Sediments and Associated Water in some River Basins of Western Uttar Pradesh"; under my supervision. It is his original contribution wnich has neither been published nor submitted for any other degree of this or any other university.

Mr. Israili, is therefore, allowed to submit the same in the form of a thesis for the award of the Ph.D. degree of Aligarh Muslim University, Aligarh.

(S.H. ISRAILI)
SUPERVISOR

ACKNOWLEDGEMENT

The author feels immense pleasure to record his sincere gratitude to Dr. S.H. Israili, Professor, Department of Geology, Aligarh Muslim University, Aligarh for his most valuable supervision, keen interest, devotion of his precious time at all stages of research and in the preparation of this thesis.

The author is highly grateful to Professor S.H. Rasul, Ex-Chairman and Professor V.K. Srivastava, Chairman, Department of Geology, Aligarh Muslim University, Aligarh for their constant encouragement and providing provision of necessary research facilities in the completion of this work.

He is particularly thankful to Dr. Krishnamurti, Director, Industrial Toxicological Research Centre, Lucknow, for giving the permission to work in his Institute and Mr. S.Q. Mehdi, Scientist-B, ITRC, Lucknow, for his kind cooperation in carrying out the analytical work and for many fruitful discussions.

Mr. S.M. Husain and Mr. P.K. Jain are highly acknowledged for typing and cartographic work respectively.

Many thanks are due to Dr. W.A. Siddiqui, Dr. S. Khurshid, Messrs. S.Q.H. Naqvi, F.A. Siddiqui, A.A. Zaidi, A.H. Khan, Farahim Khan, Mazahir Husain, Muinuddin, M.A. Wahid, Danish Raza, I.R. Ansari, M. Ajmal Ansari, Natthu Khan, Shamim Ahmad and Israr Husain, for their cooperation from time to time in the presentation of this work.

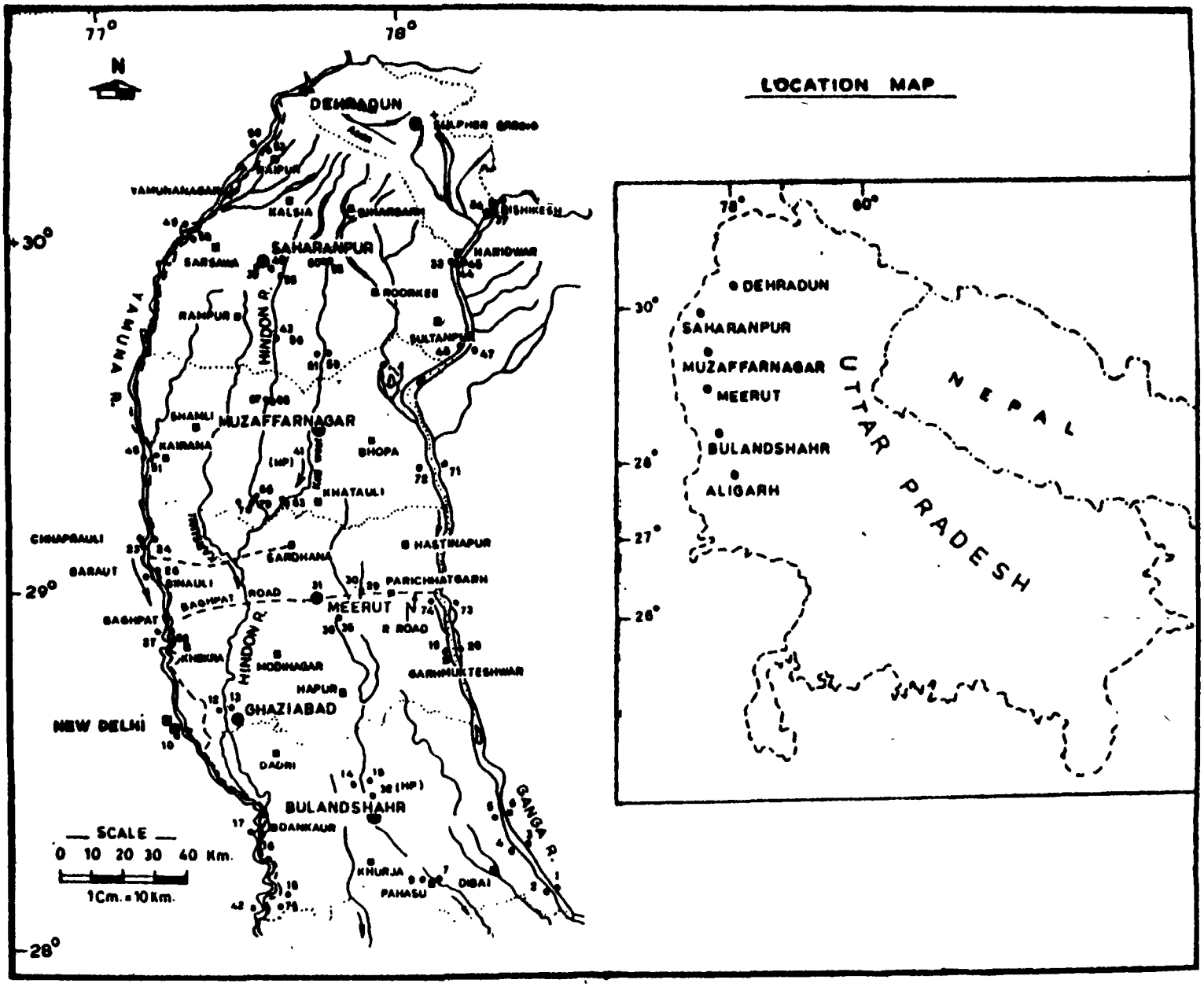
Last but not the least, the author would like to express his sense of deep gratitude to his parents and elder brother, Mr. Ghulam Madar for their constant encouragement and financial assistance to carry out the present investigations.

(ABDUL WAHID ISRAILI)

CONTENTS

CONTENTS

****
1111111111111111
****
11111111
*****
1



Map showing sampling locations i.e. Dehradun, Saharanpur, Muzaffarnagar, Meerut and Bulandshahr in western U. P.

CHAPTER I

INTRODUCTION

CHAPTER-I

INTRODUCTION

Environment includes abiotic (air, minerals, soil, water, etc.) and biotic (animal, human and plants) components. All constituents of biotic part their substance from the abiotic parts. On death, the elements constituting the biota, again return back to abiotic components then remain at equilibrium under given environmental conditions and together constitute the ecosystem. Any change brought about by artificial or natural activity puts a 'stress' upon the ecosystem and tends to change the equilibrium conditions which may or may not be good for biotic components of the ecosystem. The stresses which create harmful equilibrium conditions in the environment, cause pollution and lead to ecological imbalance.

The intensity of man's activities and diversity and magnitude of different types of wastes introduced into environment as a consequence, are increasing at an alarming rate. Discharge of these waste products creates a significant impact on environment and affect all living creatures. Hence, environmental pollution includes the release of substances which harm the quality of air, water, soil and which upset the biological cycles liking man to animal, bacterial and plants. It also includes the substances

which damage the health of man and other animals or plants, even when this damage is subtle and cause no deaths, or does not manifest itself for several decades or generations.

Environmental science has come into special significance because it covers entire ecosystem occupied by humans and deals the study of all systems, air, water, soil, energy, plant, food and population - all interact in a complex network. Environmental systems contain many complex problems which are closely linked with human problems and basic to civilization and our survival. Environmental pollution is generally referred to man made and directly or indirectly introduction through man's activity into atmosphere, hydrosphere, biosphere and lithosphere (Livingstone and Boykin, 1962; Whiteside, 1965; Frink, 1967; Wentz and Lee, 1969; Kemp, et al., 1976). Environmental movements are largely associated with various human problems such as maintenance of renewable resources, geological hazards associated with many natural disasters as earthquakes, volcanic eruptions (Eshleman, et al., 1971), hurricanes, floods, landslides, conservation of non-renewable resources, alleviate chronic droughts, indiscriminate consumption of fertilizers, pesticides, herbicides, insecticides in agriculture, sewage and industrial effluents, and natural pollution hazards.

Environmental pollution is fast becoming major problem in big cities of developing countries, where rules and regulations about pollution have not been well framed or are not strictly followed. After all, man has lived for millennia on earth exposed to dust, decomposed materials and other pollutants. During the past 150 years the reckless use of natural water resources and dangerous chemicals concomitant with heavy industrialization, high population densities, many of whom crownd into cities has caused severe pollution. Surely pollution can now be considered as a threat to entire planet.

The natural system gets upset with introduction of high pollutional loads by industrial and sewage wastes (Daneshwar, et al., 1982; Siddiqi, et al., 1984; Chaturvedi, 1984; Khurshid, 1984). With progressive civilization, the nature's final shape of consumable food stuffs are undergoing drastic changes; contaminated food pose a serious threat to mankind (Gold Water, 1971; Ulmer, 1972; Sumino, 1975; Khanna, et al., 1976). Introduction of various biological agents for agricultural and horticultural practices have made food pollution acute. Not only synthetic organic compounds but also heavy metals can cause serious pollution problems. Human exposure to toxic substances may occur through a complex matrix of sources including air, soil, and water pollution, food additives, tobacco products, pesticides, drugs, cosmetics, consumer

products, industrial work place conditions, and accidents. The diseases like cholera, typhoid, dysentery, guineaworm and jaundice would occur due to lack of sanitation facilities in towns and villages, human excreta is a principal vehicle for transmission and spread of a wide range of communicable diseases by viruses, bacteria, protozoa and helminths (Spindler, 1929; Andrews, 1934; Brooke, et al., 1955; Gupta, et al., 1972; Hays, 1976; Panicker, et al., 1978; Panicker, 1983).

This demands proper improvement in domestic water supply and drainage, proper sewage and industrial treatment and disposal, massive improvement in environmental sanitation and excreta disposal (Chandler, 1954; Panicker, 1983); segregation of industrial and commercial areas from residential areas, creation of aesthetic surroundings. An extensive assessment of research need associated with waste water treatment systems which included monitoring strategies for specific substances, detection and measurement of specific substances in waste water and residues. Control of specific toxic substances was considered to be impractical. Water pollution control practices, while continuing to be focused on conventional parameters such as biochemical oxygen demands, suspended solids, dissolved oxygen, fecal coliforms, ammonia-nitrogen, and phosphorus, will be focused increasingly on control of numerous specific substances that may or may not be toxic. Thermal pollution and air pollution also demand immediate attention and solution. Overall nature has some remarkable

mechanism for combating and eliminating its own contamination, such as natural dilution by air and water, bacterial decomposition, solar radiation (Chopra, 1984; Nammalwar, 1984) and host of various types of scavengers do a remarkably good job of maintaining a hygienic environment with intervention of man. Collection, transportation, treatment and disposal of human excreta are of utmost important in protection of health in any community.

Proper selection of crops and management in land application system in a way that minimizes environmental hazards and maintains the soil potential for crop production and waste assimilation (Rhodes, et al., 1971; Raman, et al., 1983).

SOURCE AND CLASSIFICATION OF ENVIRONMENTAL POLLUTION :

The environmental pollution can broadly classified into water pollution, air pollution, soil pollution, thermal pollution, noise pollution and radiological pollution.

Among the different types of pollution, water pollution is one of the serious problems of today. Water pollution is caused by addition of an agent whether chemical (both organic and inorganic materials), biological pollution includes (bacteria, viruses and protozoa), and physical pollution includes factors like (temperature, turbidity and suspended matters), which renders the body of water unfit for drinking or for any specific use.

Sources of Pollution :

The main sources of pollution are :

a. Sewage
b. Industrial wastes
c. Agricultural wastes
d. Radioisotope and mining wastes
e. Natural pollution
f. Population growth
g. Geology and vegetation

a. Sewage :

Sewage can be regarded as a water borne waste of man. Domestic sewage consists discharge of spent water, wash basins, bath rooms, washing machines, kitchens, etc. Besides several chemicals it also consists of living matter especially bacteria, viruses and protozoa (Beaver, 1953; Anderson, 1956; Mackie, 1956; Kabler, 1959; Bhaskaran, et al., 1961; Russel, et al., 1962; Chaudhuri, et al., 1964; Subramanyam, et al., 1969; Olaniya, et al., 1969; Singh, et al., 1969; Mathur and Kaur, 1972; Dakshini and Soni, 1979; Raman, et al., 1983; Bhide, 1983). It is an excellent medium for the development of bacteria.

b. Industrial Wastes :

Industrial wastes from chemical and petrochemical plants of various kinds and in concentrations are contained in spent waters of manufacturing establishments. They are derived in largest measure from washing, flushing, extracting and impregnating operations (Bhaskaran, 1965; Hughes, 1971; Dean, et al., 1972; Rajgopalan, 1973; Forstner and Muller, 1974; Kneip, et al., 1974; Cameron, 1978; Aggarwal and Kumar, 1978; Rao, 1979; Daneshwar, et al., 1983; Srinivasan, 1983; Taori, et al;, 1983; Jain, et al., 1984; Bilgrami, et al., 1984).

c. Agricultural Wastes :

Important pollutants to be found in surface run-off from agricultural areas are sediments, animal wastes, wastes from industrial processing of raw agricultural products, plant nutrients (nitrogen, phosphorus, potassium), crop residues, inorganic salts, mineral and pesticides (Stumm and Morgan, 1970; Jenke, 1974; Raju, et al., 1983; Handa, 1983).

d. Radioisotope and Mining Wastes :

Radioisotopes enriched discharge from nuclear plants for power generation. Discharge associated with mining and processing of

mineral deposits (Alloway and Davies, 1971; Davies and Lewin, 1974; Brown, 1977; Turekian and Rona, 1977; Davies and Roberts, 1978).

e. Natural Pollution :

The natural pollution arises from stream wash, seepage from ground water, swamp drainage and aquatic life of stream and river (Chopra, 1982; Sharma and Ghose, 1983).

f. Population Growth :

A large degree of water pollution is also caused by growth of population.

g. Geology and Vegetation :

Regional geology and vegetation also affect the water and soil pollution. The sediment resulting from soil erosion is today recognized as being the largest single pollutant affecting water quality (Robinson, 1973; Kardos and Sopper, 1974; Jones, 1979).

Kinds of Water Pollution :

Among different types of pollution, water pollution is one of the serious problems of today. Water pollution is caused by

addition of an agent whether (a) chemical, (b) biological and (c) physical.

Chemical Pollution :

Chemical pollution is due to discharge of organic or inorganic materials, pH change, depletion of dissolved oxygen and toxicity caused by trace metals or other toxic materials.

It is commonly held that many diseases hitherto regarded as spontaneous are caused by environmental pollutants. Pollution related diseases may become more common because of the exponential increase in human exposure to toxic substances may occur through a complex matrix of sources including air, land, water pollution, food and food additives, tobacco products, pesticides, drugs, cosmetics, consumer products, industrial work place conditions, and accidents. Toxic, furthermore, is a relative term that is dependent on the composition and chemical, physical and biological properties of substances as well as degree, route and condition of exposure and human susceptibility factors. The world production of synthetic organic chemicals amounted to 7 million tonnes in 1950 which reached 60 million tonnes in 1970 and will be 250 million tonnes in 1985; of 60 million tonnes produced in 1970, 20 million tonnes were released into environment. Pesticides, herbicides, disinfectants, detergents, hormonal growth regulators and antibiotics are utilized in food production from seeds, plants

and animals. Due to their intended biocidal activity and widespread use, these chemicals are identified as environmental hazards. Dichlorodiphenyl trichloroethane (DDT) a polychlorinated hydrocarbon, produced to date might have been transported to sea possibly exerting a significant impact on marine organism (Vallee, 1972; Derban, 1974; Nammalwar, 1984). Sewage and industrial wastes are classified as water pollutants because their degradation or decay leads to oxygen depletion, which affect fish and other aquatic life.

For eutrofication of lake waters, three parameters are of paramount importance, viz., carbon, nitrogen and phosphorus. Abundant supply of carbon, nitrogen and phosphorus regulate the growth of aquatic plants and inturn effect the dissolved oxygen content of lake waters. The lake water has good potential of aquatic plants like algae and these can decompose in water releasing toxic substances while simultaneously depleting the dissolved oxygen content of water, which may result in mass death of fish during the winter months in lake and other aquatic organisms (Hutchinson and Wollack, 1940; Sawyer, 1947; Murray, 1965; Pant and Sharma, 1979; Handa, et al., 1982; Israili, 1984).

Sulphuric acid which released from acid manufacturing plants, fertilizer manufacturing plants, industries and mines, has adverse effect upon aquatic organism and animal life and also causes corrosion to boats (Angino, et al., 1970; Preuss and Kollmann,1974)

Presence of sulphur in river water is an important index of industrial pollution. Sulphur which emitted during the combustion of fossil fuels in industrial energy conversion plants, is oxidised into sulphur trioxide and returned to ground water as H_2SO_4. Other sewage and industrial effluents may also contribute much of sulphur and sulphuric acid to run-off waters, Burner (1971) has given some revealing statistical analyses of industrial component 'sulphur' as total flow from land to sea, river and ocean.

Metals such as mercury (Hg), cadmium (Cd), lead (Pb), Zinc (Zn), barium (Ba), chromium (Cr) and nickel (Ni) are classified as highly toxic, poisonous and essential to biological processes. Their concentration varies within the body under normal and pathological conditions. Micro elements Ni, Cd, Ba, Al, Pb, Hg are always present in human tissues, but are generally as biologically non-essentials. Of all the heavy metals (Cd, V, Mn, Cr, Cu, Ni, Pb, Hg, As, Sb, Zn), some are among the most dangerous and least understood contaminants. Many are used industrially and so large quantities of metallic poisons are being discharged into the environment, are damaging the life of animal and plants. Some plants are very sensitive to some toxic elements which are injurious to health.(Roskam, 1972; Anon, 1972; Bakir, et al., 1973; Vahrenkamp, 1973; Derban, 1974; Stofen, 1974; Wood, 1974; Venugopal and Lucky, 1975; Aggarwal, et al., 1978; Harrison and

Laxen, 1980; Handa, 1983; Israili, et al., 1984; Khurshid, 1984; Ayyaduri, et al., 1984; Nammalwar, 1984).

Biological Pollution :

Biological pollution includes water borne diseases which are caused by pathogenic organism (bacteria, viruses, protozoa and helminths). Most pathogenic bacteria found in water are indigenous to the intestinal tract of animal and man. Among the pathogenic human intestinal protozoa, entamoeba histolytica and giardia lamblia are most commonly found in India. Infections poliomyelitis, hepatitis are viral borne and their transmission through drinking water (Brooke, et al., 1955; Lemaistre, et al., 1956; Craun, 1977). Many other water borne diseases like cholera, typhoid, malaria are transmitted by drinking water to man. The contamination of water resources by various kind of pathogenic bacteria and micro-organism is a common process (Raina, et al., 1984; Iqbal, et al., 1984; Sharma, et al., 1984; Misra, 1984). This kind of biological pollution is caused by addition of sewage from cities and towns as emphasized by Patrick (1950). Domestic sewage is the main source of living matter especially bacteria, viruses and protozoa. It is an excellent medium for development of bacteria (Beaver, 1953; Wykoff, et al., 1955; Das, 1984). Many of common infections of man (e.g. influenza, small pox, poliomyelitis and yellow fever) are virus diseases.

Effect of industrial and urban pollutant on physico-chemical and biological characters of Ganga river water is investigated by Israili (1980) and Bilgrami, et al. (1984) and biological characteristics of Yamuna river water at Agra are discussed by Sharma and Pathak (1984), Misra (1984), Khurshid (1981); Sharma and Ghose (1983). Panicker (1983) was of the opinion that human excreta may be the principal vehicle for the transmission and spread of a wide range of communicable diseases by protozoa and helminths worms.

Physical Pollution :

Physical pollution includes temperature, odour, suspended materials, turbidity, colour, taste, and radioactive wastes. Colour in ground water may be due to mineral or organic matter in solution. Turbidity is a major of suspended and colloidal matter in water, such as clay, silt, organic matter and microscopic organism. Odours and tastes may be derived from bacteria, dissolved gases, mineral matter, or phenols. Ability to hold oxygen decreases, if the temperature of water body increases (Lloyd, 1956). Suspended matter from sewage and industrial waste effluents discharge may cause damage to biological life. The primary productivity of river water has also been found affected by the coloured and cloudy nature of the waste water, which depute the dissolved oxygen content of river and make the water unfit for aquatic

biota. The water need treatment, filteration and chlorination before it to be utilized for these purposes.

Air Pollution :

Air pollution in terms of loss of health, life, property and aesthetic values are often painfully obvious. Atmospheric contaminants are generated in many ways from many sources, motor vehicle, industry, electric generating plants, space heating and incineration. In air pollution, the pollutants include gases, particulate solids, liquids of organic and inorganic nature in lower part of atmosphere, particularly in densely populated areas.

Important gaseous contaminants such as oxides of sulphur and nitrogen (SO_3, SO_2, H_2S, NO, NO_2, NO_3, N_2O_3), CO and CO_2, HF, O_3 and hydrocarbons, most gases along with dust when inhale cause pulmonary diseases and pneumoconiosis. Nitric oxide reduces oxygen- carrying capability of blood. Nitrogen dioxide damages lungs and cause eye irritation. Some hydrocarbons present in air are suspected to cause cancer. Carbon mono-oxide on entering the blood stream replaces oxygen, so necessary for blood metabolism due to its higher affinity to haemoglobin. At higher concentrations it inflicts headaches and retards physical and mental activities (Ledbetter, 1972; Perkins, 1974; Scienfeld, 1975; Rajindar, 1978; Ramanathan, 1982; Chanda, 1984; Desai, 1984).

Sulphur dioxide attacks lungs and other parts of respiratory system. Sulphur compounds are the most common and harmful pollutants for artifacts. Most common among them are SO_2 and SO_3, besides H_2S and dust particles. Atmospheric sulphur dioxide may combine with oxygen and form SO_3 which reacts with water to form sulphuric acid (H_2SO_4). The sources of atmospheric sulphur compounds are combustion, combustion of fossil, fuels and their decomposition.(Hutchinson and Whitby, 1974).

Metallic air pollutants such as Pb, Cd, Cu, Zn, As and Mn, etc. in gaseous form, are carried away from source and ultimately washed out by rain onto land or surface of the water ways. Industrial smoke containing, As, Sb, Cu, Mn, Ni, etc. is potential source of contamination of air. Recently vanadium (Duce, et al., 1974) has attracted the attention of scientists all over the world. Particulate matter in the urban air has been found to contain measurable amount of vanadium presumely arising out of burning of coal (Billing and Matson, 1972; Lee, 1972; Duce, et al., 1974; Goldberg, 1975; Patterson, et al., 1976; Winchester and Duce, 1977; Brumsack, 1977; Anderson and Smith, 1977).

Soil Pollution :

Natural soils have a capacity for adsorption, absorption and decomposition of water carried pollutants. The pollutants get decomposed by biological activity of organism living in soils. This process is analogous to self purification phenomenon in the water ways.(Robinson, 1973). This activity may proceed

either through anaerobic (specific) decomposition or aerobic process (oxidation).

The problem of maintenance of fertility of the soil is also very important. It is for this reason that the question of any deterioration in quality of soils likely to result from the sewage and industrial waste irrigation, should receive the most important consideration. The harmful effect on fertility of soil irrigated sewage or industrial waste may be due to one or more combination of following :-

1. Anaerobic condition in soil (Foster and Engelbrecht, 1973; Miller, 1974).

2. Restriction of root zone of plants and possibility of high concentration of salt (usually cation salts), particularly sodium salts in the surface water which is defined by sodium hazard (sodium adsorption ratio) (Bower, et al., 1968; Rhodes, 1971; Kardos and Sopper, 1974; Israili, 1979; Raman,et al., 1983; Chakravorty and Roy, 1984; Bagde, 1984).

Salts may retard absorption of nutrients and water may themselves be toxic and lead to highly alkaline conditions. Anaerobic condition may also retard bacteriological activity which is essential for nitrification of soils (Greenland, 1962; Meek, et al., 1969; Broadbent, 1973).

The disposal of sewage and industrial wastes on land is done by two methods : (i) irrigation - house sewage and industrial wastes are utilized in raising profitable crops while simultaneously providing satisfactory disposal of wastes, (ii) infilteration of sewage and industrial waste on land - replace the conventional treatment plants; utilizes directly both water contents manurial ingredients of sewage and industrial wastes. Complete the task of disposal.

Indiscriminate use of fertilizers, pesticides, insecticides, irrigation salts, herbicides, animal waste, crop waste disposal, nutrient and micronutrient materials, lead ultimately soil pollution in agricultural areas (Sternstorm, 1971; Robinson, 1973; Anderson, et al., 1975; Edwards and Davis, 1975; Chopra, 1984). Farm animals during summer months sit near village wells. Excreta of animals gets accumulated in small areas and leached during monsoon, adversely affected the soil. Solid wastes, are mostly discharged into dumps or landfills which as in case of urban and domestic solid wastes, are potential sources of soil pollution (Anderson, et al., 1967; Quasim and Burchinal, 1970; Walker, 1973; Meyer, 1973; Hughes, 1975). There are innumerable toxic industrial effluents that enter the body of plants and animals. These industrial effluents influence the vegetation and human population around the places of discharges. Therefore, increasing industrialization and changes in land use pattern have

resulted in general degradation of environment i.e. pollution of soil, water and air.

Industrial and sewage wastes contain high plant nutrients in solid and dissolve state, which increase ground fertility or increase the yeild (Thomas, et al., 1968; Clapp, et al., 1977; Raman, et al., 1983; Singh, et al., 1984; Rai, et al., 1984). Deficiencies of micronutrients in soils are now widespread. This has resulted because of the introduction of high yielding crop varieties. The nutrient deficiencies are also prevalent in soils of parent material lack in the essential nutrients. Trace elements such as B, Cu, Zn, Fe, Mn, Ni, Co, V, etc. are now being considered to essential for proper growth of plant. Experimental evidences suggest that the concentration of particular micronutrients, exceeding needed amount, is highly detrimental to plants causing complete damage or poor yield. Soil and irrigation water are the main source of trace elements or micronutrients (Bollar and Butler, 1966; Ayers and Branson, 1975; Das, 1977; Das, et al., 1983).

Certain elements, the so called trace elements, in very low concentrations play a very important role in the diets of humans and animals and in healthy growth of the plants. However, these elements at higher levels may prove injurious or even toxic to animal and plant life. Further some elements like cadmium,

though not directly toxic to plants at low concentration, may nevertheless accumulate in these crops to such an extent as to be toxic to human beings and animals taking those plants (Smeets and Amavis, 1981; Handa, 1983).

Micronutrients in agriculture go to soil and from soil to plant, from plant to animal and back to soil in different forms. Utilizing these wastes for crop irrigation enhancing the agricultural activity due to micronutrients (Alderfer and Lovelace, 1977).

Therefore, possible impact on environmental health of community and suggest an environmental monitoring programme for routine check of soils. Exhaustion and also 'toxicity' of soils due to prolonged application of sewage or sludge happen due to accumulation of organic matter, salts and trace elements. This can be mitigated by proper management practices like giving prolong rest period, deep ploughing, flooding, leaching of the salts out of the soil as per requirement. Application rates and methods were chosen using selected agricultural practices in order to minimise potential environment damage and maximum crop production (Raman, et al., 1983)

Thermal Pollution :

Addition of heat into open environment from hot industrial discharges, effluents and thermal power plants during the

conversion of fossil fuels into nuclear fuels. Thermal pollution is injurious to aquatic organism as well as living animals to some extent.

Noise Pollution :

Noise pollution covers energy infusion into open environment by means of sound wave transmission, in highly industrialized areas. Automobiles, loudspeakers, industries and air-crafts are the main source of noise pollution. Noise pollution affects the human health as loss of hearing, blood pressure and mental illness, etc.

Radiological Pollution :

As a result of increase in nuclear plants for power generation, contamination of ground water by radiological sources may take place. Operations like mining and milling of radioactive waste disposal can be sources of radioactive pollution. Leak or accidental releases from storage tanks or pipe lines may also cause radioactive pollution of ground water (Davies and Robert, 1978).

WATER POLLUTANTS AND THEIR TOXICITY :

Man is introducing new and complex organic, inorganic chemicals without any rigorous bio-assessment of their toxicity. In the pathway of industrial activity, metals are released into the environment in several forms, water soluble species and insoluble precipitates that contaminate rivers and lakes; metal containing particulates and volatile metal compounds that contaminate the atmosphere. Industrial workers are exposed to metal fumes, metal oxides, particulates and volatile metal compounds. The toxicity of volatile organo-metallic compounds is much higher than that of relatively non-volatile inorganic compounds. Exposure to extremely low level of environmental metal contaminants over long periods can cause permanent ill effect on health. Among the highly toxic metals, beryllium, cadmium, arsenic, lead, mercury, vanadium and their compounds are poisonous. Among less toxic elements, Ni, Co, Zn, Fe and their compounds are also harmful (Kobayashi, 1971; Chisolm, 1971; Bakir, et al., 1973; Handa, 1983).

Cadmium released into environment by zinc and lead refinery plants, paints and pigments manufacturing units. The acute toxicity of cadmium has been known for about 100 years. In 1940, many death occurred in Sweden while manufacturing alkaline nickel-cadmium batteries. However, the grave consequences were realized only after the 'itai-itai byo' incident in Japan (Kobayashi, 1971). Cadmium has no known biological function. It inhibits enzymes containing thiol group. Cadmium is a respiratory poison and may

contribute to high blood pressure and heart diseases (Bryam, 1971; Kobayashi, 1971; Nordberg, 1977).

Of all the heavy metals, increasing concern has been expressed about quantities of lead present in the environment. It has long been known that lead compounds are abortificients and women working with lead have shown a high rate of miscarriages. Tetralkyl lead compounds produced as antiknock additives for gasoline are highly toxic. They affect skin, gastrointestinal tract, lungs, central nervous system and cause respiratory diseases. Children have a lower lead tolerance than adults. They damage central nervous system causing lead encephalopathy and lead neuropathy (Banerji, 1950; Chisolm, 1971; Anon, 1972; Stofen, 1974; Sircar, et al., 1975; Chakravorti and Bhar, 1978; Srivastava, 1978; Khapalia, et al., 1981; Harrison and Laxen, 1981; Handa, 1983; Kumar, 1983).

Mercury occurs in the form of sulphides in the earth crust. It is released into environment during its production and by human activities like combustion of fossil fuels, waste disposal and industrial activities. Organic mercurials and inorganic salts of mercury are well known toxicants, the main target of attack being brain and kidney. Elementary mercury is employed in the electrolytic production of chlorine and sodium hydroxide. Phenyl mercury is used in paper and pulp industry and other mercurial compounds are used as fungicides. Among the mercury compounds,

alkyl-mercury derivatives are the most toxic, embryotoxic and mutagenic (Bakir et al., 1973; Derban, 1974). Mercury poisoning leads to impairment of vision and muscles, madness, paralysis, coma (Goldwater, 1971; Fujiki, 1972).

Manganese is largely used in manufacturing of ferromanganese alloys, pigments, paints, ceramics and dry cell batteries. Manganese poisoning leads the respiratory illness and neurological disorders (Niyogi, 1958; Balani, et al., 1967; Israili, 1980; Chandra, et al., 1980; Sondhi, 1983; Handa, 1983).

Arsenic is widely distributed in biosphere. Arsenic compounds are believed to cause cancer of skin, lungs, and liver (Aston, et al., 1975). Despite severe toxicity of arsenic, it is used considerably in agricultural (as pesticides and defoliant) and electronics (in manufacturing of semi-conductors). In Taiwan, widespread occurrence of black-foot disease resulted from high levels of arsenic (2.5 ppm) in ground waters (Haberer and Normann, 1971).

Chromium and nickel are extensively used in electroplating-polishing, paints and pigments industry. The concentration of nickel and chromium in different body tissues has been found to evaluate occupational exposure to their salts. Monitoring of these metals in urine has been suggested as the most sensitive, reliable and practical index of exposure (Lahiri,1957; Handa, et al., 1983).

PREVIOUS WORK ON WATER AND SOIL POLLUTION :

The first incident of poisoning by mercury compounds were reported in 1866 in London and in 1887 in Germany. The most severe incident of man-made mercury poisoning occurred during 1959 and 1972 due to use of wheat seed treated with mercurial fungicides. Finally, eight years after the Minamata (1953) and Niigata (1965) tragedy, organomercurials were accepted as deadly toxic.

Bhaskaran, et al. (1965) have reported the pollution in river Gomti in different seasons. The water of river Gomti received considerable pollution load from communities and industries located on the river bank. High BOD values were found to persist throughout the entire stretch of the river surveyed.

The Minamata Bay disaster during the early 1950s concerned the mysterious neurologic illness and human fatalities among the fisherfolk who subsisted mainly on fish. Since this disease also prevailed among the local sea birds and household cats, the investigations led to discover that consumption of high concentrations of Hg-compounds accumulated in fish and shellfish had evoked disastrous and through the nutritional food chain it affected the humans (Goldwater, 1971).

Somayajulu and Rama (1972) have analysed fish from coastal waters of Bombay and showed that all varieties of fish contained about 100 ng/gm of mercury.

The physicochemical analyses and characteristics of Ganges river water at Varanasi were determined by Agarwal, et al. (1976). Israili (1980) studied the metal contents from Garhmukteshwar in Meerut district to Kachhla bridge in Etah district in bank soils and waters of the river Ganges and noticed an increasing trend in their concentration in the downstreams of the river.

Lichtfuss and Brummer (1977) studied heavy metal pollution of Elbe sediments. The sediments were highly polluted with Zn, Cu, Cr, Pb, As, Cd and Hg. Sediments showed high Zn, Cu, As, Hg, and low Cr, Pb and Cd contents when compared with those of Rhine.

Akeada (1977) surveyed water and substances of river and sea around the Nagasaki prefecture for trace heavy metals during (1969-74), the substrata of the Nagasaki and Sasebo bays were found heavily polluted with Cd, Pb, Zn and Hg. The average content of Cd in polished rice in highly polluted districts was found to be 0.44 ppm which is 6-11 times of that of normal districts.

Baier (1977) investigated the lead distribution in the cape fear river estuary. All the concentrations of Pb in cape fear

estuary were found well below the recognised lethal values for the aquatic life.

Agarwal, et al. (1978) have analysed heavy metal contents in waters and associated sediments of Sursagar lake of Baroda, which revealed very high concentration of sodium and potassium. High contents of lead was found due to automobiles and petrol vehicles. The cadmium contents were also higher than the maximum permissible limits.

Agarwal and Kumar (1978) found Hg, Zn and Cu in quite high concentration from the effluents of Rohtas paper Industry and Kanoria Chemical Factory, Renukot (U.P.), resulting in a lack of aquatic biota due to high concentration in these waters.

Reece, et al. (1978) analysed sediments samples collected from Coeurd Alene river northern Idaho which indicated that the main stream and south fork of the river were contaminated with heavy metals (Cd, Pb, Mn and Zn) from local mining operations.

Tsal, et al. (1978) reported analysis of the sediments from the Iowa river. Fe, Mn, Ba, Zr, Sr and Rb were present in concentrations of more than one ppm.

Reddy (1979) studied the sediments transported from the Genesee river watershed to lake Ontario. The metal concentrations in µg were as follows : Al, 6660 $\pm$ 2620; Cr, 14 $\pm$ 9; Co, 18 $\pm$ 7; Fe,

15060 ± 7312; Mn, 424 ± 212; Ni, 23 ± 13; Pb, 67 ± 40 and Zn, 69 ± 37.

Rao, et al. (1979) have analysed water samples from Kalu river and investigated heavy metal contents (Zn, Cu, Fe, Pb and Hg). Kalu river water receives industrial effluents and its water is utilized for cultivation. Sediments, soils and plants on the rive bank showed fairly high contents of Hg, Pb, Cd and Cu. Milk of buffaloes and cows of the villages near the river had high concen tration of Hg, the range being 1.6 - 15.0 µg/l. High concentratior of Hg in soil had perhaps been transported to plant and transferre to the cattle grazing on the near bank. River also contained Hg, Pb, Cd and Cu with variable concentration of trace metals. Crops which grow near the bank of river, showing fairly high metal contents like lead, cadmium and copper.

Dutta, et al. (1980) investigated lead pollution in water and soil sediments along roads in Calcutta city. All water and soil samples indicated high lead contents.

Sharma (1980) reported water pollution of Ganga river, that is one of the highly polluted rivers in the world. High pollution load was investigated in Hoogly river near Calcutta. Bhargava (1977), Ajmal, et al. (1982) have studied the water quality monitoring parameters in Ganga, Yamuna and Kali rivers.

Khapalia, et al. (1981) have determined lead content (0.02 ppm) around Kanpur in surface and subsurface waters. The lead content is well below the maximum permissible limit (0.1 ppm).

Das Gupta (1982-83) indicated that recent report of fish killing and arsenic poisoning in ground water source near Calcutta are alarming. During the investigation of Ganga river, they found maximum value of BOD (13.2 mg/l) at Kanpur, sodium content at diamond harbour (2632 mg/l) and calcium at Ghaziabad (40 mg/l). pH value of Ganga river water is found to lie between 7 and 9 (indicates slight alkaline nature).

Handa, et al. (1982) have reported trace element content of Cu, 0.03 ppm; Fe, 4.9 ppm; Mn, 1.1 ppm; Zn, 0.22 ppm; in sediments of Naini Tal lake. They however found Na to occur in usually low concentrations of 0.85 ppm, while K was seen to be 167 ppm. Pande and Das (1980) have studied the metallic contents in water and sediments of lake Naini Tal. The metals Cu, Co, Zn, Pb, Mn, Li, Na, K and Ca were analysed by atomic absorption spectrophotometer in lake water and sediments at five sampling stations. The levels of metal in bottom sediments were found to be more higher than those in water.

In the series of papers, Handa (1974, 1975, 1977) has described occurrence and distribution of trace elements in natural water in Uttar Pradesh. Natural waters in Uttar Pradesh has revealed that

most of the trace metals like, Ag, Cu, Zn, Co, Mo, Ni, Cr, Mn, Fe, Pb and F are present in concentration below the upper limit specified for potable waters. Handa, et al. (1982) have described eutrophication of Naini Tal lake and found highest value 930 microgram/litre of PO_4. The lake water, therefore, has good potential of aquatic plants, while simultaneous depleting the dissolved oxygen contents of lake water, which may result in mass death of fish. Handa, et al. (1982) have described pollution of ground water by nitrates in Uttar Pradesh. The highest value found being 694 mg/l NO_3 in well waters from Hastinapur in Meerut district. Handa (1983) has described pollution of Ganga river water at Kanpur (U.P.). They determined 120 microgram/l lead concentration at Kanpur.

In the series of paper, Israili (1979 a, b; 1978; 1980; 1983), Israili and Khan (1978), Israili, et al. (1978 a, b, c, d, e; 1984) have described trace elements geochemistry of water bodies and its impact on regional biology and their possible remedial measures in rain water, surface and subsurface waters in western Uttar Pradesh. Israili (1983) has described environmental impact of sanitary landfills in high water table areas in parts of Union Territory of Delhi and reported a high concentration of metal contents in shallow ground water aquifers.

Handa, et al. (1981) have described pollution of Gomti river water in Lucknow and suggested that the 'in mass death' of various fish fauna could be due not only to the stress created by depletion of oxygen but also to the presence of high concentration of Cu and Zn. Handa, et al. (1983) have determined Cr content as high as 21 mg/l in hand pump water from Kanpur.

Khurshid (1981, 1984) described heavy metal contents in western Yamuna river basin. He reported the concentration of iron in that area as high as 5.95 ppm, zinc 8.56 ppm, cadmium 0.25 ppm, copper 3.6 ppm, chromium 1.2 ppm, nickel 16.5 ppm and lead 0.18 ppm and their high potential toxicity to various biological forms. Siddiqi, et al. (1983) analysed various samples collected from surface and ground water bodies in Hindon river basin and indicated that trace elements are creating much more water pollution. The average value of metallic contents, i.e. Cu 0.08 ppm, Cr 0.33 ppm, Mn 0.17 ppm and Cd 0.02 ppm, exceeds the World Health Organisation (WHO) limits (1978).

Hasan, et al. (1983) a survey was conducted to study trace metal in ground water. Arsenic, cadmium, chromium, copper, lead, manganese, mercury and zinc were determined in well waters. Results revealed that mercury was almost absent and cadmium was in traces. Other trace metals except manganese were present far below their permissible limits. The ground water surveyed

appears not to constitute any significant danger to the water consumers due to trace metal pollution in Nagpur. Ground water pollution due to sewage percolation in Jaipur have been reported by Olaniya, et al. (1978).

Mehrotra, et al. (1984) have recently analysed metals, i.e. Hg, Cd, Pb, Zn, Ba, Zr, Ca, Al, P, S, Si and Ti in bank sediments of river Ganga at Varanasi, many of them are highly toxic and considered responsible for health hazards.

AIMS AND OBJECTIVES OF THE PRESENT STUDY :

The area under study covers the north-western part of Ganga-Yamuna doab of western Uttar Pradesh and is situated between two principal rivers of North India; Yamuna in the west and Ganga to the east and comprising the following districts Dehradun, Saharanpur, Muzzafarnagar, Meerut, Ghaziabad, Bulandshahr and some parts of Union Territory of Delhi. The major and most important rivers flowing through the area besides Ganga and Yamuna are Hindon and Kali and their various tributaries. All rivers flow from north to south direction.

The present area of study has been selected to find the causes and extent of water and soil pollution due to heavy industrialization. Assessment and causes of environmental pollutional

intensity due to dispersion of metal contents in water and associated soil. Problem also deals with the environmental impact of agricultural inputs (fertilizers and pesticides), quality of irrigation water, drinking water standards, nutritional hazards and sodium adsorption ration (SAR). Criteria for irrigation management and proper selection of crops to enhance the agricultural activity in the study area, besides environmental monitoring programme for routine check for soil conditions, deficiencies of micronutrients because of the introduction of high yielding crop varieties, deficiency and toxic symptoms of trace metals and remedial measures for usar soil reclaimation, are some of the main objectives of this study.

Classification of soils according to SAR values for irrigation, plant response and crop selection of saline and alkali soils, relative salt tolerance of crop plants, origin and nature of saline and alkali soils and soil characterization will also be undertaken. Such studies will also helpful to find the probable sources of water pollution and soil pollution which might be utilized tor suggesting remedial re-measures in future.

The study would therefore include :-

1. Collection of both surface and subsurface waters (mainly river water) and associated soil samples and other necessary informations pertaining to research work.

2. To collect data and information relevant to water use and water pollution. Such data,information would include all aspects; e.g. physiography, geology, hydrology, demography, landuse, agriculture, industry waste-use, waste-water, discharge, etc.

3. Chemical determination of commonly found cations, e.g., Na, K, Ca, Mg and trace metals, e.g. Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr, Cd in water and associated soil samples.

4. Interpretation and chemical correlation of metal contents between water and associated soil samples.

5. Metal contents and pollution intensity in water and soil sediments and their impact on the productivity of the region.

CHAPTER II

PHYSICAL ENVIRONMENT

CHAPTER-II

PHYSICAL ENVIRONMENT

INTRODUCTION :

The present chapter deals field characteristics of study area where stress has been laid down to ascertain the effects of various environmental parameters like topography, geology, river-system, climate and rainfall, crops, hydrogeology, mineral resources and soil types and their impact on water quality of the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Bulandshahr and Ghaziabad falling in the upper Ganga Yamuna doab.

LOCATION :

The study area covers north-western part of Ganga-Yamuna doab of Uttar Pradesh and is situated between two principal rivers of north India, Yamuna to the west and Ganga in the east. It is the most important, fertile and thickly populated part of Uttar Pradesh. The area under study lies in Ganga Yamuna doab comprising the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad, Bulandshahr and some parts of the Union Territory of Delhi.

TOPOGRAPHY

The area is montaneous expose of Ganga-Yamuna alluvium with gently undulating topography and average ground slope is 0.38 per kilometer towards south and southeast coinciding with ground water slope. The bangar surface of Ganga Yamuna doab has a rather variegated topography interspersed by break of slope due to terrain formation and sand belts (bhur).

The district of Dehradun comprises two distinct tracts, the montane and submontane. The mountains of district are the Himalaya and the Siwalik ranges. The district of Saharanpur has three distinct tracts, i.e. ghar, khadar and bangar. The ghar is sub-montane belt below the Siwalik with varying width and intersected by numerous hill rivulets, bangar covers the remaining part of the district. The districts of Meerut, Muzaffarnagar, Bulandshahr and Ghaziabad are almost uniform alluvial plain with slight slope from north to south or southeast.

GEOLOGY :

The district of Dehradun consists various rocks and minerals, i.e. slate, quartzite, grit, limestone, dolomite, and marble, etc. The districts of Saharanpur, Muzaffarnagar, Meerut,

Bulandshahr and Ghaziabad comprise the alluvial deposits with admixture of sand, silt, clay and minerals like Reh (admixture of sodium carbonate, sodium chloride and sodium sulphate with traces of calcium and magnesium) and nodular kankars.

RIVER SYSTEM :

The major and the most important rivers flowing through the area are Ganga, Yamuna, Hindon and Kali Nadi, and their various tributaries. All the rivers flow with the general north-south trend. Yamuna flows along the western border of the districts, Dehradun, Saharanpur, Muzaffarnagar, Meerut and Bulandshahr, whereas river Ganges flows along the north-east border of districts Dehradun, Saharanpur, Muzaffarnagar, Meerut, Bulandshahr and finally joins at Allahabad. Hindon river flows through the districts of Muzaffarnagar, Meerut, Ghaziabad and ultimately joins the Yamuna river in Bulandshahr near Dadri. Kali-west emerges from Saharanpur in north-east and flows through Muzaffarnagar and finally joins the Hindon river near Khatauli in Muzaffarnagar district. Kali-east emerges from Muzaffarnagar and passes through Meerut and Bulandshahr.

CLIMATE AND RAINFALL :

The climate is subtropical and reflects considerable variation in the plains of Uttar Pradesh. Total rainfall during the whole

year is over 1000 mm and climate may be described as humid to sub-humid. Rainfall intensity decreases towards south and west of the state. The districts of Aligarh, Meerut and Bulandshahr experiences semi-arid type of climate.

CROPS :

Entire alluvial deposit in the basin is endowed with rich soil nutrients and yielding annual harvests of crops for the past thousands of years without much serious deterioration. No wonder that the world's largest and richest rice bowl lies in the gangetic alluvial trough. Besides rice, this tract produces a wide variety of crops including sugarcanes, wheat, jowar, bajra, millet, pulses, maize, cotton, jute and many other food and commercial crops.

HYDROGEOLOGY :

The area under study covers the most fertile part of Uttar Pradesh and considered to possess one of the best ground water reservoirs in the world. Ground water occurs in large reservoirs beneath the water-table and water is mainly of alkaline type but there are many pockets in Agra, Aligarh, Mathura and Etah districts where water is not suitable for drinking purposes.

Pathak (1976) has divided the state of Uttar Pradesh into five hydrogeological zones on the basis of occurrence, movement, storage and physiography of the area.

Zone	Subzone
1. Himalayas	i. Lesser and central Himalayas
	ii. Sub-Himalayas or Siwalik
2. Intermontane Doon Valley	
3. Alluvial Tract	i. Bhabar
	ii. Tarai
	iii. Central Ganga Alluvial plain
	iv. Marginal Alluvial plain
4. Vindhyan Terrain	
5. Bundelkhand Granite Terrain	

Doon Valley :

It is a spindle shaped tectonic valley which is underlain by unconsolidated sediments comprising various types of gravels and intercalated sands of various grades and clays.

Ground water occurs under water table, perched and confined conditions. The granular zones lie at depth ranging in between 24 meters and 139 meters whereas depth to water table ranges

from 22 meters to 76 meters. Discharge varies from 50 to 180 meter^3/hour with drawdowns ranging in between 0.7 meters to 8.5 meters.

Alluvial Tract :

The alluvial tract is considered to be the most important ground water resource in Uttar Pradesh. It is underlain by unconsolidated sediments dating from Pleistocene to recent in age. This zone is further subdivided into four sub-zones.

(a) Bhabar :

This sub-zone has unassorted gravels, sand and intercalated clays. Saturated granular zones comprising of boulders to sand and clay sized fractions occur in between 140-150 meters below the surface. The gravels are generally composed of pebbles or cobbles of quartzites, granites, sandstones and slates.

Ground water occurs under water table conditions under 30 meters or below the ground level. The discharge of the tube-wells varies from 97 to 227 cubic meter/hour for drawdown between 2.68 meters and 0.68 meters.

(b) Tarai :

Coarse sand, gravel with intercalated clay lie more or less parallel at the southern margin of the Bhabar. Sand and gravel serve good water bearing materials and occur in the depth range of 25 meters and 298 meters.

The piezometric head in the flowing wells of this horizon lies in between 6.63 meters and 8.92 meters above the ground water level. In the non-flowing wells, it ranges between 1.55 meters and 11.34 meters below the ground level. Most of the tube-wells constructed in this region register a free flow, ranging in between 80 to 210 cubic meters/hour. In the non-flowing wells, the discharge varies from 2 to 8 meters.

(c) Central Ganga Alluvial Plain :

The southern limit of the Tarai zone is marked by a wide zone of alluvium which is composed of gravel, sand, silt, clay and kankar. It lies between Yamuna and Ganga and extends up to its confluence in Allahabad which marks the limit of this zone. The demarcation between gravel, sand, silt, clay and even kankar is neither smooth nor uniform. The major portion of the area under study is covered by this zone.

Ground water occurs under unconfined conditions in surface or near surface aquifers and under confined conditions in deep water aquifers. This is the region where ground water occurs at deeper levels but it is very little exploited as compared to its immense storage and ease of availability.

Sub-surface geological studies indicate a thickening of the alluvium from west to east. According to seismic refraction studies done by Oil and Natural Gas Commission (O.N.G.C.), the depth of alluvium near Raya in Mathura district has been reported to be around 220 meters. Its depth gradually increases towards the east and near Hathras it occurs at a depth of 260 meters. In recent drilling by Central Ground Water Board (C.G.W.B.) for a deposit well at Aligarh, the Vindhyan shales were encountered at a depth of 379 meters. Subsequently, granite was encountered at a depth of 500 meters at Panki in Kanpur district that disproved the earlier estimation of around 2000 meters thick bed of alluvium in this region. At Kurni in district Jaunpur, the eastern limit of the State, granite basement has been reported to occur at a depth of 538 meters. It indicates that the maximum depth of potential aquifers in this region varies in between 220 meters and 380 meters, and water occurs under free to confined and semi-confined conditions. Depth of water table from the ground level ranges between 2 to 12 meters and discharge between 100 and 300 cubic-meter/hour for drawdown of 6 to 10 10 meters.

(d) Marginal Alluvial Plain :

This is the region occupied largely by the Bundelkhand gneiss and the Vindhyan rocks of silt, clay, kankar and sands of various grades, compose the sediments. Ground water occurs both under confined and unconfined conditions.

In the western Uttar Pradesh this type of marginal alluvium occurs at the western most margin of the region where Vindhyan rocks are exposed at a depth ranging in between 220 to 280 meters in Mathura and in Naujhil area, the bed rock has been reported to be in between 100 meters and 150 meters. Water table varies between 5 and 25 meter below ground level with a discharge ranging in between 50 and 230 cubic-meter/hour for drawdown from 4 to 15 meters.

SOILS :

Mainly alluvial soils lie in Ganga-Yamuna doab, are divided into two groups.

1. The Newer Alluvium known as Khadar
2. The Older Alluvium known as Bangar

The hardpans of kankar of impure iron oxide are specially common in Indogangetic alluvial plain of U.P. and Bengal. In U.P. older alluvium forms bangar or high ground terrains, a few meter above the present level of river valleys while low land in which rivers flow, is called Khadar. The older alluvial soils are fairly mature, often leaching to formation of calcareous nodules, iron concretions, ferruginous clay pans and usually comprise well drained reddish-yellow, silty, sandy and clayey loams. Saline and alkali soils are found in many parts of Ganga-Yamuna doab area, locally such soils are known as Usar (infertile) with white colour reh deposits.

Usar soils with reh deposits cover an area of 5500, 11342, 7355, 16039, 10497 hectares (Table-I) in the districts of Saharanpur, Muzaffarnagar, Meerut, Bulandshahr and Ghaziabad respectively. Large tracts and worst hit districts by ravages of salt infestation are Bulandshahr, Mainpur, Aligarh, Etah, Farrukhabad, Etawah, Kanpur, Unnao, Fatehpur, Allahabad and Lucknow. For the purpose of agriculture, saline and alkali soils are regarded as a great problem which require special remedial measures and management practices for the profitable utilization. In the recent past the various studies have undertaken for suggesting remedial measures to reclaim the Usar soils in this part of the basin.

Aggarwal and Gupta (1968) have studied saline and alkali soils in various part of India and suggested various remedial measures for their reclamation. Aggarwal and Mehrotra (1958) have surveyed and classified various type of soils in Uttar Pradesh. Several experts of the Planning Commission (1933) in their report on waste land including saline-alkali and waterlogged lands, have suggested several remedial measures for the reclamation of these soils.

Ippal, Aggarwal and Kibe (1966) have reported various reclamation measures of saline and alkali lands. Navill (1926), Dhawan (1964), Kanwar (1962) and Taylor (1940) have also studied and suggested many reclamation methods of saline and alkali soils, amendments and economic aspects of utilization.

Classification of Soils :

Soils are broadly classified into ten groups under different lithological, climatic and pedogenetic conditions in Ganga basin (Das Gupta, 1980), i.e. (i) Mountain soils (ii) Sub-montane soils (iii) Alluvial soils (iv) Red soils (v) Red and yellow soils (vi) Mixed red and black soils (vii) Deep black soils (viii) Medium black soils (ix) Shallow black soils (x) Laterite and lateritic soils. Alluvial soils can be divided into ten soils groups according to recent systematic corresponding

nomenclature (Das Gupta, 1980) is given below within parentheses.

a. Bhabar soils (Ustorthents)
b. Tarai soils (Haplaquents)
c. Older Alluvial soils (Paleustalfs)
d. Saline and saline-alkali soils (Natrargids, salorthids)
e. Younger Alluvial soils (Udifluvents)
f. Calcareous Alluvial soils (Ustochrepts)
g. Calcareous sierozermic soils (Calciorthids, haplargids)
h. Deltatic Alluvial soils (Tropaqualfs)
i. Coastal Alluvial soils (Haplaquents)
j. Coastal sandy soils (Quartzipsamments).

The bhabar soils comprising loose detrital permeable matter and cover sediments deposited in sub-Himalayan foothills and intermontane valley of Dehradun, Saharanpur districts, while Tarai soils occur below the bhabar belt are usually waterlogged.

Soils are said to be saline if they contain excess of soluble salts, and sodic if they contain an excess of sodium. Non-saline sodic is applied to the soils with high concentration of sodium but not soluble salts. According to sodium salt contents, they are classified into three classes which are as follows.

(a) Saline Soils :

Saline or saline-nonsodic soil is used in connection with soils for which the conductivity of saturation extract is more than 4 micromhos/cm at 25°C and exchangeable-sodium-percentage is less than 15. Ordinarily, the pH is less than 8.5. Saline soils are often recognised by the presence of white crusts of salts on the surface.

(b) Saline-Alkali Soils :

Saline-alkali soils contain soluble salts and sodium in quantities great enough to interfere with the growth of most crop plants. Saline-alkali is applied to soils for which the conductivity of saturation extract is greater than 4 micromhos/cm at 25°C and exchangeable-sodium-percentage is greater than 15. These soils form as a result of combined processes of salinization and alkalization. Under conditions of excess salts, the pH readings are seldom higher than 8.5 and particles remain flocculated.

(c) Nonsaline-Alkali Soils :

Nonsaline-alkali soils contain enough exchangeable sodium to interfere with growth of most crop plants, but they do not

contain an excess of soluble salts. Nonsaline-alkali is applied to soils for which the exchangeable-sodium-percentage (ESP) is greater than 15 and conductivity of saturation extract is less than 4 micromhos/cm at 25°C. The pH readings usually range between 8.5 and 10. The high pH results from interaction of exchangeable-sodium with carbonic acid formed biologically, producing a mixture of sodium bicarbonate and carbonate in the soil solution. Dispersed and dissolved organic matter present in the soil solution of highly alkaline soils may be deposited on the soil surface by evaporation, darkens their colour hence they are called black alkali soils.

CHEMISTRY, ORIGIN AND REMEDIAL MEASURES OF USAR SOILS :

Chemistry :

The alluvial soils are generally clayey in nature. In the study area at various places soils have a capacity to accumulate various salt contents on the surface which locally called usar. The usar or reh soil mainly composed of sodium chloride, sodium carbonate, sodium bicarbonate, sodium sulphate, and other sodium salts with traces of calcium and magnesium salts and kankar. These soils also contain various minerals like quartz, feldspars, dolomite, gypsum, chloride and biotite and fragments of ferruginous and manganiferrous minerals in the form of kankar. Probable source rocks

are sandstone, quartzite, dolomite, grit, slate and other Siwalik rocks in the study area.

Origin :

The cations of sodium get fixed on the surface of colloidal clay particles. Sodium salts tend to deflocculate among the pore spaces in soil particles and affect the porosity and permeability of soils. The phenomenon of sodium salts coming up through solution by capillary action due to rise in ground water table, form a thin encrustation on the surface after evaporation of water, this process is called salt efforescence. Salt accumulation in the form of thick reh deposits are seen widespread in the districts of Meerut, Bulandshahr and Muzaffar-nagar during the dry season. During monsoon the soils remain submerged and become impermeable when they dry up.

The main causes leading to development of saline and alkali soils are arid climate, high sub-soil water table, poor drainage, irrigation with water containing soluble salts and water logging.

Remedial Measures :

Various remedial measures are adopted for the reclamation of the salt affected land in various districts of the study area.

1. In the usar tracts the reh efforescence at surface could be removed either by scrapping off the surface or by flushing with water to wash away the excess salts.

2. Artificial drainage to lower the water table by 1 to 1.5 meter below surface by open on the tile drains. Better irrigation practices and lining of canals to prevent the seepage.

3. Growing salt tolerant crops like rice, sugarcane, sweet clover and bermuda grasses. The crops cover the land surface and reduce evaporation. Voelcker (1897) suggested the Cherat experiment and found it successful. The field was embanked to hold rain water and then ploughed in and experimental grasses were grown. Again, another attempt on the recommendation of Leather (1914) was made and a number of plots in Aligarh were kept flooded with water for several months. Water was then let off and paddy was transplanted. Subsequently barley was grown. If this process is continued for some years, the mild type of soils could be reclaimed.

4. Soil Amendments : Hardan and Abdullah (1972) strongly recommended the external sources of cations for improvement of saline-sodic and sodic soil materials used as sources of cations.

(a) Gypsum : Dutt, et al. (1971) and Poonia, et al. (1973) considered gypsum to be an efficient requirement for ESP and stated that amount of gypsum to be applied depends on amount of Na, to be displaced and amount of Na and gypsum in irrigation water.

(b) Sulphur and Sulphuric Acid : Sodic soils that have a good supply of calcium can be reclaimed with sulphur as the response to sulphur is lower than gypsum. Martin (1953) stated that sulphur and sulphuric acid were efficient amendment under calcareous sodic conditions.

(c) Vegetation and Organic Matter : Gowda and Pratt (1973) found that growing of tolerant crops and addition of organic matter to a calcareous sodic soils reduced the pH and ESP. Hildreth (1955) suggested that on sodic land that does not respond to leaching, the growing of any kind of vegetation is an efficient means of reclamation.

Other amendments are also made by adding Al_2SO_4 and Fe_2SO_4. After chemical amendments, Na-soil converted into Ca-soil, the soluble product of reaction like $NaHCO_3$ and Na_2SO_4 have to be removed by leaching through flooding.

$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2$

$2(Na\text{-soil}) + CaCO_3 = Ca\text{-soil} + Na_2SO_4$ (soluble)
leached out by flooding

$CO_2 + H_2O = H_2CO_3$

$CaCO_3 + H_2CO_3 = Ca(HCO_3)_2$

$2(Na\text{-soil}) + Ca(HCO_3)_2 = Ca\text{-soil} + 2NaHCO_3$ (soluble)
leached out by flooding

5. Application of Manure and Organic Matter : It liberates CO_3^{++} which dissolve in water forming carbonic acid which increases solubility of $CaCO_3$ in soil.

The effective management of saline alkali soils involves mechanical and agronomical practices to keep down the harmful effects of salts. Careful levelling of the land is essential for the uniform spread of water and effective dykes should be constructed where sand is slopy. Easily decomposable organic matter, e.g. paddy straw, paddy husk, etc. should be applied in these fields. Salt tolerant crops like rice, sugarcane should also be grown.

Table-I : Districtwise Information regarding area of Agricultural Land (1981-82)

Area	Saharan-pur	Muzaffa-rnagar	Meerut	Buland-shahr	Ghazia-bad	Total
Cultivated land	548252	417311	391447	436398	2585507	4378915
Forest land	77315	7276	7993	10370	2555	105509
Usar land	5500	11342	7355	16039	10497	50733
Grass land	504	748	534	1749	516	4061
Other land	65904	44880	45585	36321	33643	226333
Fallow land	5499	9357	7980	8851	6899	38586

Area in hectare

Table-II : Districtwise Means of Agricultural Irrigation (1982-83).

District	Wells	Rahats	Electric tube-wells	Diesel pum-sets	Govt. Tube-wells
Saharanpur	1802	741	12110	42760	642
Muzaffarnagar	1863	991	21996	25638	477
Meerut	6256	2202	33181	11882	609
Bulandshahr	14397	3304	30189	15025	568
Ghaziabad	4480	1188	4623	21158	278
Total	28798	8426	102099	116463	2574

Table-III : Districtwise population of Human Being and Livestock (1981-82)

District	Total population	Female	Male	Urban	Rural	Livestock
Saharanpur	2673653	1213775	1459878	723658	1949995	768438
Muzaffarnagar	2288410	1047324	1241086	495044	1793366	598875
Meerut	2766496	1262225	1504271	865638	1900858	482415
Bulandshahr	2349530	1090464	1259066	460891	1888639	407532
Ghaziabad	1866778	849875	1016903	632166	1234612	185922
Total	11944867	5463663	6481204	3177397	8767470	2443182

CHAPTER III

INDUSTRIAL WASTES AND THEIR DISPOSAL

CHAPTER-III

INDUSTRIAL WASTES AND THEIR DISPOSAL

INTRODUCTION :

There are about 18 sugar mills (pollution load - 16561 MT/day), seven textile mills (pollution load - 8143 kg/day) and ten pulp and paper mills (pollution load - 127 tonne/day) which control major part of pollution load and wastewater in the districts of Saharanpur, Meerut and Ghaziabad, and their wastes are discharged into Hindon and Kali rivers, land and ponds near the industries. Except these industries there are three rubber and plastic (pollution load - 48.5 tonne/month) industries, 15 chemical (pollution load - 11055 kg/day) manufacturing industries, 11 metal and non-metal (pollution load - 534.5 tonne/day) processing industries and also various kind oil manufacturing and dairy units which are discharging indiscriminate amount of wastes into Kali, Hindon, Yamuna and Ganga rivers in the study area. Many of these industries are situated very far from river channels, therefore their wastes are discharged in pools, ditches, open lands near the sites and some of it is channelized through nalas, rivulets, tributaries, etc. to the river Ganges. Significant pollutants from various industries are BOD, COD,

suspended solids, dissolved solids, coliforms and various heavy metals such as Cu, Cr, Zn and Fe, Pb, and Ni, etc.

The present chapter therefore deals with the location, production capacity, pollution load and situation of various industries, disposal of industrial wastes on land and site selection criterion of wastewater disposal in the study area. A brief description about the various pollutional loads is given as follows.

RIVER POLLUTION DUE TO INDUSTRIAL WASTES :

The discharge of crude or partially treated sewerage, industrial wastes, mine wastes, and agricultural wastes into a river contributes by the commonest sources of river pollution. Chemical pollution due to presence of organic or inorganic substances is, in general, the commonest type of river pollution. The organic pollution is due to the presence of organic compounds and materials are broken down by micro-organisms present in river water and dissolved oxygen is used up in these reactions. If the organic pollution load is small and dilution by well oxygenated stream water is high, sufficient dissolved oxygen may break down the organic matter completely to relatively harmless and odourless end products. The river thus recovers naturally from the effect of pollution and is said to have undergone 'self purification'. However, massive pollution by organic matter

causes exhaustion of dissolved oxygen or depletion of oxygen. The remaining organic matter is then broken down by different set of bacteria - anaerobic bacteria which do not regive free oxygen but can utilize combined oxygen in the form of nitrates, sulphates, phosphates and organic compounds, etc. putrefaction then occurs, resulting in breaking down of organic matter to different set of end products, some of which have objectionable odour (Klein, 1957).

Many industrial wastes contain corrosive inorganic acids or alkalies which may cause extensive damage to stream by breaking down its natural buffer system and altering its normal pH values. Acids and alkalies can destroy bacterial and other micro-organism and do inhibit or even prevent self purification of a stream.

The common toxic inorganic substances are free chlorine, ammonia, hydrogen, sulphate, and soluble sulphides and salts of many heavy metals (Cu, Zn, Pb, Ni, V, etc.). Any appreciable amount of these compounds may hinder self-purification of rivers and may even kill fish and other aquatic lives.

The dissolved solids or soluble salts which are commonly found in rivers include chlorides, sulphate, nitrate, bicarbonates and phosphates of sodium, potassium, calcium, magnesium, iron and manganese. In small concentrations these are harmless to

fresh water fish but in larger amount these may cause corrosion of pumps, pipelines and other structures made of metal or concrete.

Many industrial wastes discharged to a river have a pronounced colour which they may impart to river. The colour is due to in most cases to organic dyes, but there are some highly coloured substances of mineral origin, especially compounds of Fe and Cr. Interaction between two different industrial wastes in a river or between the industrial waste and substances present naturally in river, sometimes produce quite intense colouration. One example of this is the reaction between mine water and natural bicarbonate alkalinity of river to give an unsightly reddish brown opalescence and eventually a deposit of ferric hydroxide.

An important physical characteristic of sewage and the most of the industrial wastes is the degree of cloudiness or turbidity mostly caused by colloidal or suspended matters that settle only with difficulty. As a rule, the more pronounced the turbidity, the stronger is the sewage of industrial wastes and worse is its effect upon a river.

Concentration of various organic pollutants and their harmful effects on fish have studied in detail and reported by Bhaskaran, et al. (1965) in Daha river; De Mukherjee (1970) from Rayon Mill

effluents; Verma and Dalela (1980) in Kalinadi river. Recent report of fish kill and arsenic poisoning in Ganga river water near Calcutta is reported by Das Gupta (1984).

Taori, et al. (1983) discussed that dairy effluents in Nagpur are readily putrescible and cause considerable nuisance and pollution when discharged in the inland water bodies without adequate treatment. Singh, et al. (1983) revealed that effluents from Vanaspati Ghee plant in Jaipur have oils and high BOD. Badrinath, et al. (1983) and Josh (1982) have studied of textile wastewaters (3500 M^3) which indicate colour due to use of various dyes, high pH and BOD values (1500 mg/l).

Daneshwar, et al. (1982) have discussed that wastewaters have high pollution load due to inorganic sulphate, suspended solids, BOD, COD. This wastewater discharged into Hoogly estuary from Titaghur Paper Mills at Kankinara in West Bengal.

Cameron (1970) in Heathcote river; Cairns and Dickson (1972) in south Virginia river; Kim (1974) in Han river; Olaniya, et al. (1976) in Chambal river, etc., have reported biological aspects of river pollution. Rivers in general were found badly polluted in industrial areas and downstreams but fairly clean at upstreams.

The water qualities of Adhyar river (Sundaresen, 1965); Christina river (Shane, et al., 1971); Barren river (Harlow and Row, 1972); Pandu river (Gupta and Pandey, 1980); Nigerian rivers (Ajayi and Osibanjo, 1981), etc. were surveyed, in order to determine the effects of industrial and municipal wastes that were discharged into rivers.

TYPES OF INDUSTRIES AND THEIR PRODUCTS :

The area under study is highly industrialized, agriculturally productive and densely populated. A wide varieties of industries have developed during the course of last twenty years, which released untreated industrial wastes into rivers, streams, canals, pits, ponds, lagoons, thereby enabling the wastes to migrate down to the ground water table. There has been an increasing pollution in Yamuna, Ganges, Kali and Hindon rivers in the vicinity of industrial units. Many large and small scale industries are located in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Bulandshahr and Ghaziabad, which are grouped as follows.

1. Sugar factories
2. Cotton textile mills
3. Pulp and Paper industries
4. Rubber and plastic industries

5. Chemical manufacturing industries
6. Paint and varnish industries
7. Soap, powder, detergent and glycerine manufacturing industries
8. Metal, non-metal and alloys manufacturing industries
9. Hydrogenated oil manufacturing industries
10. Dairy and food products.

Sugar Factories :

There are eighteen sugar mills in the districts of Saharanpur, Muzaffarnagar, Meerut and Bulandshahr, most of the sugar mills are located near the Hindon and Kali rivers in the study area. Significant pollutants which are produced in sugar processing are BOD, COD, suspended solids, NH_3, dissolved solids, etc. Total pollution load (COD, BOD, SS) and volume of wastewater released during sugar processing is 16561 metric tonne/day and 225×10^5 gallon/day respectively, that was produced due to cane-crushing of 34631 metric tonne/day. Location, production capacity and pollution load and other waste effluents of all sugar mills are listed in Table-I.

Water pollution due to sugar mills is of great concern in districts of Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr, because these districts contribute the major part of the total production of sugar in India. These sugar factories discharged the untreated wastes indiscriminately into

the Hindon and Kali rivers, land or municipal sewers. These wastes are very putrescible and cause considerable water pollution, due to low pH, high value of BOD (806 to 1660 mg/l), COD and volatile solids.

Cotton Textile Mills :

There are seven textile mills in Ghaziabad, Meerut and Saharanpur districts but one of the biggest textile industry is situated in Saharanpur (Lord Krishna Textile Mills) which produced 44504 spindles/day of cotton yarn. Raw materials which are used in cotton textile mills are chemicals, viz., enzymes, detergents, caustic soda, bleaching powders, H_2O_2, Na_2CO_3, sulphur and napthol and other dyes. The wastes from textile mills have the significant pollutants like BOD (658 mg/l), COD (994 mg/l), dissolved solids, suspended solids (1248 mg/l), various heavy metals, viz., copper, zinc, chromium, etc. The production of 1000 kg of wool leads typically to 1500 kg of impurities (wool fibres, sand, grease, burns) and 300 to 500 kg of process chemicals with 250 kg BOD. The water consumption works out to be about 108 litres per kg of finished cloth. The total pollution load and volume of waste-water is 8143 kg/day and 814300 litre/day respectively from all these textile mills. Major part of these wastes are regularly being discharged in the inland water bodies without adequate treatment. Table-I, thus reveals the location, production and total pollution load discharged by all these textile mills.

Pulp and Paper Industries :

There are ten industries of paper and allied products in Saharanpur, Meerut and Ghaziabad districts. Star Paper Mills Limited and Aggarwal Paper Mills are the two large scale paper industries in the study area and are located in district Saharanpur. It is estimated that the production of one tonne paper requires 1100 kg chemicals (caustic soda, chlorine, lime, salt-cake, china clay, talc, coating clay and alum) and 184 tonnes Bamboo and wood as raw materials. The known significant pollutants from the paper mills are BOD, COD, suspended solids, dissolved solids, bacteria, ammonia, sulphite-liquor, pentachlorophenol and also other various trace metals, viz., copper, zinc, chromium, iron, etc. For the production of one tonne of paper, total pollution load contributed has been worked to about 334 kg suspended solids, 149 kg COD and 75 kg BOD. Paper mills consume maximum quantity of water next to steel mills. Water used in paper mills as pulp preparation, transportation, cylinder cleaning and lubrication. About 360 m^3 of water is used in the production of one tonne of paper. About 50% of wood used as input is eventually discharged as waste material.

Total pollution load and volume of wastewater is 127.1 tonne/day and 44280 m^3/day respectively are discharged due to production of 164 tonnes of paper per day (Table-I). Star Paper Mill in

Saharanpur district alone discharges its about 26 metric tonnes daily as wastewater into Hindon river near village Tapri and due to discharge of this huge amount of waste, the colour of river water has completely been changed into dark brown colour with a sharp lowering of pH and reduction in dissolved oxygen content.

Rubber and Plastic Industries :

There are three big rubber and plastic manufacturing industries in Ghaziabad district of the study area, which are named as Foreign Exporters and Manufacturers, Mohan Nagar, Ghaziabad; Universal Plastic Limited, Bharatnagar, Ghaziabad and Jindal Rubber Limited, Ghaziabad, which are producing 50 tonne plastic/month, 75 tonne plastic/month and 50 tonne/month rubber material respectively. Total waste which is being discharged from plastic industries is 48.5 tonne/month due to production of 175 tonne plastic/month in the study area, whereas from the rubber production results in high BOD and COD, bad taste and odour, chemicals, viz., butadiene, styrene in soap solution and coagulated with an acid brine solution, hydrocarbons and organic compounds, as well as various reagents.

Chemical Manufacturing Industries :

There are 15 chemical manufacturing industries which are producing a wide variety of various water pollutants by

manufacturing of various chemicals such as acids, bases, synthetic fabrics, pesticides, detergents and other organic, inorganic compounds in districts Saharanpur, Muzaffarnagar, Ghaziabad and Meerut. Total pollution load which is discharged into Kali, Hindon and Yamuna rivers is of the order of 11055 kg/day in the study area (Table-I). Recently, mercury and lead trace metals have caused great concern in chemical manufacturing wastes.

Paint and Varnish Industries :

There are many paint and varnish manufacturing plants in district Ghaziabad, which are using various chemicals and minerals. Total pollution load from these units in area is 46 tonne/day due to production of 51000 tonnes of paint and varnishes per year. Major part of these effluents is discharged on the land. Location, production and pollution load of all these plants are given in the Table-I.

Soap, Powder, Detergent, and Glycerine Manufacturing Industries :

There are seven soap, powder and detergents manufacturing factories in district Ghaziabad, and Saharanpur. Total pollution load is 36.25 tonne/day by producing 27345 tonnes of soap, powder and detergents per annum in the district of Ghaziabad.

Total pollution load, location, production capacity of all these industries are given in the Table-I.

Metal and Non-Metal Industries :

There are 11 metal, non-metal and alloy manufacturing industries in districts Ghaziabad and Muzaffarnagar. Total pollution load and other wastes which are discharged into river water and on the land are 534.5 tonne/day which are produced by manufacturing of the 23900 tonnes of alumina bricks per year and 646500 tonnes of steel per year. Steel mills produce wastewater from the coking of coal, washing of the blast furnaces, fuel gases. The wastewater and solid wastes tend to be acidic and contain, cyanogen, phenol, ores, coke, limestones, alkali, oils, fine suspended solids and various trace metals viz., chromium, lead, nickel, cadmium, zinc, copper, silver. etc. Total pollution load, location and production of all these industries are given in Table-I.

Hydrogenated Oil Manufacturing Industries :

There are seven hydrogenated industries in the districts of Ghaziabad, Meerut and Muzaffarnagar which are releasing total pollution load of 176.40 tonne/day and other solid wastes due to production of 31×10^4 tonnes hydrogenated oils and ghee per

annum and one lakh litre of wastewater every day. This wastewater contains very high BOD value of the effluents to the separate layer of oil in the surface which prevents its access to atmospheric oxygen and also dissolved oxygen. Significant pollutants are oil, ghee, grease, COD and BOD. Total pollution load, production capacity, location of oil industries, etc. are given in Table-I.

Dairy and Food Product :

There are several dairy factories in the districts of Muzaffarnagar, Ghaziabad, Saharanpur, Meerut and Bulandshahr. Significant pollutants are pH, BOD, COD, dissolved solids suspended solids, settleable solids in dairy product processing, etc. Total pollution load (BOD, COD, suspended solids) is 5.20 tonne/day due to 2157 tonne/day of dairy product processing, major part of this load has been discharged into Hindon river water. The dairy industry produces organic wastes high in protein, fat, carbohydrates and lectose from milk and cheese processing. The production of cheese is an important BOD source. A number of biological methods can used to treat these wastewaters. The anaerobic packed bed up flow filter can serve as a good and economic method for pre-treatment of dairy wastewaters. Pollution load, location, and capacity of production of all dairy industries are given in Table-I.

Miscellaneous :

Other industries have also released a wide variety of pollutants in study area. Leather and tannery wastes have high total dissolved solids, salt, sulphides, chromium, alkali metals, etc. Polishing of optical glasses produce red wastes while laundries have turbid wastes and both of them alkaline and contain organic solids. Radioactive wastes result from nuclear power plants, fuel processing plants, hospital and research laboratories, etc.

Total pollution load (COD, BOD, suspended solids) and waste-water, a major portion of which is disposed into Hindon, Kali, Ganga and Yamuna rivers that amounts to 16655.56 metric tonne/day, and 23 x 10^6 m^3 per day respectively in districts of Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr of western Uttar Pradesh. Total solid wastes which are discharged on the land near factories are 26735.4 metric tonne/day, significantly from sugar, textile and paper mills. These waste waters have significantly higher value as compared to ISI standards. An adequate treatment of waste water and selection of suitable disposal site of waste is therefore necessary before its disposal.

DISPOSAL OF INDUSTRIAL WASTES ON LAND :

There are three locations for the disposal of the wastes, which include surface, atmosphere, and land. The land represents not only an appropriate disposal site for many wastes but also provide an opportunity to manage with minimum adverse environmental effects. The application of the manure, sewage, sludge, municipal wastewater and industrial waste on land for both disposal and fertilizer values have been practised for centuries. The challenge is, however, to utilize the chemical, physical and biological properties of the soil as acceptor for industrial wastes, with minimum undesirables in the soil and to the quality of ground water and surface run-off. The soil and waste must be managed carefully as a total system to obtain the best use of the resources.

The disposal of waste on the land is often a beneficial recycle. The industrial wastes contained in municipal sludge are disposed off directly onto the land include material mined from deep in the earth or chemical conversions of simple organic compounds. Many of these waste components may be foreign to the upper soil horizon. A control is, therefore, necessary in order to avoid biological toxic concentrations of such materials in the upper soil phase.

The land disposal of the wastes incorporate organic and , inorganic recycle and reuse. Little is known about the waste assimilative capacity of a soil. Each soil has its own maximum capacity to assimilate and treat wastes and to renovate waste-waters. This capacity is related to soil characteristics, environmental conditions and crops to be grown. The growth of the crop on the disposal area is important to the success of the use of the land for waste disposal. A growing crop is essential to increase the rate of adsorption, evaporation and transpiration in order to avoid soil erosion.

The potential treatment mechanism in soil are several. These include biological oxidation, ion exchange, chemical precipitatior adsorption and assimilation in growing plants. The biological, physical and chemical processes in a soil provide a treatment of the wastes that incorporate the factors and the components of the present day biological and advanced waste treatment methods for municipal and industrial wastes.

Soil as a physical filter (Thomas and Kerr, 1974), utilize this filtering capacity of the soils for disposal or renovation of municipal effluents and industrial wastewaters and the approaches include septic tank-soil absorption system, cropland irrigation system, surface disposal system, and ground water recharge system. Soil serves as a chemical filter (B.G. Ellis, 1974), chemical alteration (organic or inorganic) may lessen the environmental

impact such as conversion of organic materials to CO_2, thereby reducing BOD carried in water or may increase environmental hazard such as conversion of organic nitrogen to nitrate. Soil as a biological filter (R.H. Miller, 1974), group of organisms (bacteria actinomycete, fungi, protozoa, algae, soil micro-organism, macro-animal and higher plants), significant function of these organism is degradation of organic compounds of waste material applied to soils. Significance of higher plant in renovation of liquid wastes on land has been well explained by Kardos (1967, 1980) and Sopper (1971).

SITE SELECTION CRITERION FOR WASTEWATER DISPOSAL :

Considerable attention must be given to the site selection and land management to be assured that the irrigation area will not be chemically degraded and agricultural productivity destroyed. Knowledge of the soils, geology and hydrology may of significant help when selecting sites for wastewater renovation to ensure that a high degree of renovation is achieved for a prolong period, to ensure that ground water recharge and/or reuse can be achieved and to minimize secondary environmental problems that may result from wastewater irrigation projects.

The concentrations of harmful trace elements and toxic substances not likely to be removed into the renovation media will have to

be controlled in irrigation waters or reduced or eliminated in advance of land disposal. Extensive soil water and ground water pollution and pollutants can persist for generations within the subsurface (Richard. R. Parizek, 1974).

It is therefore suggested that a detailed report pertaining to the resource position, drainage, soil type and chemistry, population intensity, social status and other elements of environmentally compatible micro-level planning of that very region be made before establishing any major/minor industry of any industrial complex. It would not only help in combating pollution but would also help in maintaining a balance in the various eco-system units and the selection of proper disposal sites.

Table-I : Information regarding number of Industrial Units, their products and capacity and Pollution Loads in Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr districts.

Name of Industrial and number	Product and Capacity	Pollution Load (COD, BOD, SS, SW, etc.
1. Sugar Mills (18)	34631 MT/day cane-crushing	16561 MT/day
2. Cotton Textile Mills (7)	197302 Spindles/day	8143 Kg/day
3. Pulp and Paper Mills (10)	164 tonne paper/day	127.1 tonne/day
4. Rubber and Plastic Industries (3)	175 tonnes plastic/month	48.5 tonne/month
5. Chemical Industries (15)	O_2 - 17.8×10^5 M^3/day Acids - 2500 tonne/year Glycerine - 300 tonne/year N_2 - 60×10^6 M^3/year CO_2 - 25×10^6 M^3/year	11055 Kg/day
6. Paint and Varnish Industries (7)	51000 tonne paint and varnish/year	46 tonne/day
7. Soap, powder and Detergent Industries (7)	27345 tonne/annum	36.25 tonne/day
8. Metal and Non-Metal Industries (11)	Alumina Bricks - 23900 tonne/year Steel - 646500 tonne/year	534.5 tonne/day
9. Hydrogenated Oil Industries (7)	31×10^4 tonne/annum	176.4 tonne/day
10. Dairy and Food Product (several)	2157 tonne/day	5.20 tonne/day

BOD - Biological Oxygen demand
COD - Chemical Oxygen demand
SS - Suspended solids
SW - Solid wastes

Table-II : Districtwise BOD, Toxic and Metallic Pollutants (1977-78).

Name of District	Population		Water supply in KLD	Waste Water in KLD	BOD in Kg/day		Toxic Load (Kg/day)	
	Urban	Rural			Domestic, urban, Rural	Industrial	Non-metallic	Met.
Dehradun	65265	184614	9700	7760	5651	2	2	0.0
Saharanpur	369257	1210270	28363	22690	31054	24210	13.5	0.1
Muzaffarnagar	204156	1228477	20700	16560	23531	105265	22.9	0.1
Meerut	221547	1094659	21450	17160	23554	38340	5.3	26.
Bulandshahr	102250	685610	8340	6672	12639	1620	2.7	2.8

KLD - Kilolitre per day

Table-III : Information regarding districtwise contribution of Urban Domestic and Urban Industrial Pollution Load (1980-81).

Name of District	Urban population	Sewered population	Water supply in KLD	Water waste in KLD	Urban BOD Load, Kg/day	
					Domestic	Industrial
Dehradun	325313	290277	37174	28867	15161	4838
Saharanpur	549532	362739	70988	50794	22097	16833
Muzaffarnagar	311829	14325	32935	16088	7176	105397
Meerut	600140	368887	100384	70213	23554	14683
Ghaziabad	462810	79705	60948	37856	16034	97016
Bulandshahr	314986	5070	32133	15676	7278	4770

Table-IV : Heavy Metals employed in Major Industries (Dean, et al., 1972).

Name of Industries	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Ni	Sn	Zn
1. Pulp, paper mills, paper board, building paper, board mills		x	x		x		x	x		x
2. Organic chemicals, petrochemicals	x	x		x	x		x		x	x
3. Alkalies, chlorine, inorganic chemicals	x	x		x	x		x		x	x
4. Fertilizers	x	x	x	x	x	x	x	x		x
5. Petroleum refining	x	x	x	x			x	x		x
6. Basic steel works foundries	x	x	x	x	x		x	x	x	x
7. Basic non-ferrous metals works, foundries	x	x	x		x		x			x
8. Motor vehicles, aircraft plating, finishing	x	x	x		x			x		
9. Flat glass, cement, asbestos products, etc.		x								
10. Textile mill products		x								
11. Leather tanning, finishing		x								
12. Steam generation power plants		x								x

CHAPTER IV

ENVIRONMENTAL IMPACT OF NUTRIENTS AND PESTICIDES

CHAPTER-IV

ENVIRONMENTAL IMPACT OF NUTRIENTS AND PESTICIDES

INTRODUCTION :

Nitrogen, potassium and phosphorus are essential plant nutrients. In order to improve crop yields, many farmers are using synthetic fertilizers which include interalia urea, ammonium sulphates, ammonium phosphates, super phosphates, KCl and K_2SO_4, etc. Except the synthetic fertilizers, farmers are also using the various pesticides which are chlorinated hydrocarbons, organo-phosphates or sulphonates with some inorganic compounds. The use of synthetic fertilizers and pesticides have undoubtedly contributed crop yield and to human health, but have also produced a number of adverse effects, including widespread pollution of natural environment accompanied by damage to marine and inland fisheries, beneficial insects and occasional over poisoning to man.

Problem can arise from over use of the agricultural chemicals, because a part of this added fertilizer is taken up by plants, some may be immobilized in the soil and/or lost by volatilization or lost by erosion (run-off) and partly may be leached down to saturated zone along with return irrigation flows. Excessive and unscientific use of nutrients and pesticides may cause water

and soil pollution. Phosphorus and potassium fertilizers are readily adsorbed on soil particles and seldom constitute a pollution problem. Nitrogen on the other, is partially used by plants or adsorbed by soils. The soils in western Uttar Pradesh are poor in nitrogen, but rich in K-minerals. About 13660.5 tonnes of pesticides and insecticides and 212 thousand metric tonnes of fertilizers were used in agricultural development in western Uttar Pradesh every year, on the average.

However, with introduction of high yielding varieties and a desire to get the maximum yield from the soil, the use of synthetic nutrients and pesticides have become inevitable, hence an early remedial solution is necessary to prevent the various pollutional hazards in the area.

Arora, et al. (1980) have pointed out that not all the fertilizers applied is taken up by plants but a part is lost by leaching, etc. In their studies on the utilization of fertilizers, they reported heavy losses of fertilizer nitrogen under monsoon conditions.

Singh and Sekhon (1977) reported that the largest movement of nitrate below the root zone occurred with harvest fertilizer application combined with shallow root system crops like potatoes. Considerable work has already been done by Handa (1974, 1975 a, b, c) on pollution of ground water by nitrates.

Handa (1976, 1977, 1979 and 1980) has studied that ground water was found to contain anomalously high concentration of these constituents, indicating that contrary to normal belief about fixation of these elements in the soil, leaching of these constituents to the saturated zone does take place under favourable conditions. Although degradation of water quality by contamination with K and PO_4 is not so injurious to health as in the case of nitrates, this fact does indicate the need to use proper fertilizer, crop and water management practices to prevent degradation in ground water quality. Further, where such K and PO_4 enriched ground waters discharge into surface water bodies, they may encourage growth of aquatic plants, which may affect navigation adversely or on decomposition these aquatic plants may release toxic substances into the aqueous environment which may affect the aquatic organisms, while simultaneously depleting the dissolved oxygen content of water.

In India high concentrations of nitrate in ground water have been reported by Handa and Maitra (1964); Chowdhury and Handa (1973); Handa (1975, 1977); Israili (1978, 1980, 1981 and 1983); Misra (1980) and Handa, et al. (1982).

NITROGEN FERTILIZERS :

Presence of excessive nitrate in potable waters has been correlated with occurrence of methemoglobinemia (blue baby

disease). Similar to man, livestock are also subject to adverse effects when they consume water that contains high nitrates, although concentration of nitrates producing deleterious effects varies with type of animal species. Most health authorities have limited the nitrate content of potable waters to be around 50 mg/l NO_3 (W.H.O., 1971 and I.C.M.R., 1975) but in Denmark and Czechoslovakia the limit is 25 mg/l (Nilsson and Rannek, 1975). For livestock use, the U.S.E.P.A. (1973) suggested a limit of 100 mg/l NO_3, while Hart (1974) in Australia recommended a range of 90-200 mg/l NO_3, in water to be used for them. Studies carried on the nitrate concentrations in dug well water from different parts of Uttar Pradesh have revealed that the nitrate concentration in some cases exceeds 200 mg/l. The highest value was found to be 694 mg/l NO_3 in a well water from Hastinapur in Meerut district (Handa, et al., 1982). The ideal dose of N-fertilizer to grow more and more food grains, is 100-120 kg/hectare. Addition of more quantity of N-fertilizer 30 kg/hectare to grow wheat after paddy crop is often added.

Total Annual Consumption :

Annual consumption of N-fertilizer in the district Dehradun (Fig. 1) was 1144 MT, 1182 MT, 1224 MT, 1250 MT; in Saharanpur (Fig. 2) was 28773 MT, 27387 MT, 32278 MT, 36278 MT; in Muzaffarnagar (Fig. 3) was 27489 MT, 27346 MT, 31209 MT,

37409 MT; in Meerut (Fig. 4) was 32383 MT, 34087 MT, 40239 MT, 48116 MT; in Ghaziabad (Fig. 5) was 17943 MT, 15867 MT, 16149 MT, 17889 MT; and in Bulandshahr (Fig. 6) was 26516 MT, 26647 MT, 33499 MT, 39878 MT, in the years 1978-79, 1979-80, 1980-81 and 1981-82 respectively (Table-V). Total annual consumption of N-fertilizer in all these districts of study area was 134248 MT, 132516 MT, 154598 MT and 180820 MT, in the years 1978-79, 1979-80, 1980-81 and 1981-82 respectively. It reveals a considerable increase in the consumption of N-fertilizers for agricultural purposes during all the corresponding years in all these districts of the area studied.

Nitrogen Chemistry and its Sources in Soil :

The nitrogen fertilizers used in Uttar Pradesh are : urea, ammonium sulphate, calcium ammonium nitrate and ammonium phosphate. Farmyard manure and 'gobar gas slurry' which are also high in nitrogen are also used. Atmospheric nitrogen fixation may take place through symbiotic fixation by bacteria of Rhizobia species, Non-symbiotic fixation by Azotobacter and Clostridium bacteria, fixation by blue green algae mostly of the family Nostocoaceae and photo-chemical fixation. A part of this nitrogen so fixed may be released to soil. Similarly organic nitrogenous matter also contributes to the total nitrogen pool in the soil. Under aerobic conditions, in warm climate, as is prevalent during the major part of the year in

Uttar Pradesh, all soluble nitrogen compounds are fairly and rapidly converted to nitrates in soil; the form in which it is rapidly adsorbed by soil particles to any significant extent and NO_3 ions not adsorbed by plant roots, will tend to move rapidly through the soil, more or less along with water front. The NO_3 ions present in the soil, can be removed in four different ways,viz. they may be taken up by plant roots; they may be taken up by soil micro-organism and converted into humus (immobilization); they may undergo denitrification and may be leached out of the soil root zone to the saturated zone and get detected there (Handa, et al., 1981).

The anthropogenic activities have modified the nitrogen cycle both on the micro and macro scale. The human excreta in big cities of Uttar Pradesh finds its way into drains which is emptied into river. There are numerous industries that release industrial waste effluents to the environment, most of them without any treatment. The most important factories containing nitrogen compounds are the nitrogen fertilizer industries manufacturing urea, however, most of these wastes are drained into the streams and rivers. Irrigation with surface water can also contribute nitrogen species to ground water through return irrigation besides addition of green manure extensively used in Uttar Pradesh to supply nutrients to crop and improve soil structure. A tonne of compost contains 5 kg of nitrogen (Raheja, 1966). Synthetic nitrogen fertilizers commonly used are : urea, calcium ammonium nitrate, ammonium phosphate, ammonium sulphate, ammonium nitrate, ammonium chloride and urea ammonium phosphate,

further add to the nitrogen concentration in the ground water.

Nitrate is adsorbed directly by plant roots, however, ammonium ions are also take up base exchange complex of the soil and are ultimately oxidised to nitrate ions under aerobic conditions by bacterial action. The rate of nitrification differs in different soils and is affected by pH of the soil, moisture conditions, temperature, etc. Under anaerobic conditions nitrate gets reduced to ammonia. The characteristics of various forms of N, in natural water are given in the Table-I.

Nitrate Leaching to Ground Water :

The chemistry of nitrogen in soil may be followed in two broad groups, the decomposition of the organic matter containing nitrogenous matter into amino acid, which are further degraded into ammonium sulphate, etc. (aerobic proteolysis) or into ammonia amines etc. (anaerobic proteolysis). The other group is the hydrolysis of urea to ammonium and its subsequent oxidation to nitrate. These nitrates in so far as they are not taken up by the plants tend to leach down to saturated zone and degrade the quality of receiving waters. Nitrates of most elements are quite soluble in water and the nitrate ion is not adsorbed onto the clay complex of the soil but like chloride, moves along with water front. Walter, et al. (1975) indicated

the immobilization ammonification and nitrification, all interacted significantly to affect N-leachings. According to him, all nitrogenous fertilizers regardless of the form in which applied are ultimately changed to mobile NO_3 by natural processes. The nitrogen use efficiency (NUE) may be tentatively given by the following relationship.

$$NUE = \frac{\text{N-removed in crop + N in crop residue}}{\text{N in fertilizers + N fixed + N in farmyard}}$$

Health Hazard :

Excessive use of nitrogenous fertilizers might alter the chemical composition of food grains and pose a serious health hazard according to a survey conducted by the Industrial Toxicology Research Centre, Lucknow. In a report, it is said that high levels of unassimilated nitrate-nitrogen had been found in some leaf crops like Spinach. Infant consuming baby food processed from such contaminated products developed severe blood circulation trouble and related disease (Mokee and Wolf, 1963). There is also a possibility that the concentration of nitrogen and nitrate-nitrogen in food material may interact and produce nitrosamines which are known to be cancer (Shuval, 1975, Mirvish, 1975) producing the report said.

Higher concentration of NO_3 has been reported to cause an illness (methemoglobinemia-nitrate cyanosis) of infants. Blue coloration of skin, i.e. cyanosis, is an indication of nitrate

poisoning. Nitrate in water may also be responsible for the occurrence of goiter. During the year March, 1976 and April, 1978, few cases of animal deaths were reported from Nagaur district of Rajasthan where animal died after drinking water from the well containing nitrate contents ranging from 886-1772 mg/l (Misra, 1980). The cause of poisoning in animal is due to their conversion either in the food stuff or within alimentary tract of the livestock. This reduce nitrate (nitrite) which is prone to convert ferrous ion of haemoglobin into ferric ion, forms methemoglobin, which is the basic reaction mechanism of poisoning in animals also.

Prevention :

It is therefore obvious that proper scientific soil water and fertilizer management practices must be applied to prevent degradation of water quality in the phreatic zone. Excessive use of N-fertilizers must be avoided. Over irrigation is also undesirable as it facilitates leaching down of NO_3. Similarly location of septic tanks, proper management of human and animal wastes in villages is essential to prevent contamination of ground water from these sources.

PHOSPHATE FERTILIZERS :

The important phosphate fertilizers are monocalcium phosphate (CaH_2PO_4), dicalcium phosphate ($Ca_2(HPO)_2$), ammonium polyphosphate and di and tri superphosphates. Phosphorus is another essential plant nutrient. Phosphorus is one of the least mobile elements of plant nutrients. The phosphorus which is not taken up by plant is fixed in soil zone especially in the presence of aluminium and iron oxides. Calcium phosphate is quickly precipitated if calcium is available in the soils. Phosphate in the soil is transported to plant by diffusion over a very short distance and not flow of water because of its low solubility. The loss of phosphate in water is not significant, especially in relation to quantities released from municipal and industrial waters (Raju, et al., 1983).

Total Annual Consumption :

Annual consumption of P-fertilizer in district Dehradun (Fig. 1) was 268 MT, 336 MT, 305 MT and 350 MT; in Saharanpur (Fig. 2) was 5684 MT, 6599 MT, 7162 MT and 7811 MT; in Muzaffarnagar (Fig. 3) was 5055 MT, 4986 MT, 5697 MT and 6912 MT; in Meerut (Fig. 4) was 6505 MT, 7244 MT, 7311 MT and 7510 MT; in Ghaziabad (Fig. 5) was 3735 MT, 3238 MT, 3992 MT and 4719 MT; in Bulandshahr (Fig. 6) was 6565 MT, 5755 MT, 7309 MT and 9809 MT in the years 1978-79, 1979-80, 1980-81 and 1981-82 respectively in each district. Total annual consumption of P-fertilizers in all districts of area was

27812 MT, 28158 MT, 31776 MT and 37120 MT in years 1979, 1980, 1981 and 1982 respectively (Table-V). Graph has shown that the annual consumption of P-fertilizer is increasing every year in all districts of the study area.

Phosphorus Chemistry and its Source in Soil :

The application of inorganic phosphorus fertilizers in the soils usually results in an initially rapid rise in soluble phosphorus as PO_4. However, this situation changes rapidly and even if the solution diffusing out of a pellet of granular super-phosphate placed in a moist soil has a phosphate concentration of about 4 molar. Its concentration a few millimeters from the granules may be only 10^{-5} to 10^{-6} molar (F.A.O., 1972). The phosphate ions are thus rapidly immobilized in soil either through adsorption on the surface by hydrated oxides of iron, aluminium, silica, etc. or through interaction with iron and aluminium (on acid solids) or with calcium (on alkaline soils).

Stumm and Morgan (1970) tabulated several species of phosphates which occur in dissolved form in natural waters. The principal sources for phosphates are the phosphate bearing minerals in rocks (through their weathering), biological transfer (through assimilation and dissimilation process including agriculture) and industrial uses (soaps, detergents, water treatment, etc.).

Health Hazard :

Excessive phosphate in domestic water would be undesirable as they will make a buffering action on the gastric juices. Phosphates are particularly present along with nitrates from excellent nutrient material for algal and other fungal growth. Such growths may not only cause problems in water supply system, but indirectly cause adverse effects on human beings by becoming the breeding places for pathogens. Because of the fact that phosphate analyses are generally not commonly done, there are no internationally accepted upper limits of phosphate prescribed. The reported Canadian and Australian limits are very low, being 0.066 and 0.2 mg/l respectively. The U.S. Environmental Protection Agency has fixed an upper limit of 0.15 to 0.31 mg/l of PO_4 for surface waters.

Control Measures :

The soil conditions and its chemistry give us necessary clues in locating the well sites. If the natural waters are rich in phosphates, necessary reagents can be added to participate the excess phosphate. The phosphate contaminating ground waters because of the human interface can be controlled by suitable statutory regulations and stipulations. Better management of irrigation/fertilizer inputs should also be worked out in association with Agronomists and soil scientists.

POTASH FERTILIZERS :

Potassium is an essential plant nutrient and play an important role in maintenance of cellular organisation by regulating permeability of cellular membranes and keeping protoplasm in a proper degree of hydration by stabilizing the emulsions of highly colloidal particles. Potassium deficiency in water is known to produce imbalance in plants and also results in decreased level of photo-synthesis and in the content of total and reducing sugars. Deficiency gives rise to abnormal accumulation of ascorbic acid in plants and deficiency of potassium also affects adversely the formation of polysaccharides and proteins which are the condensation products of primary sugars. Moderate quantities of potassium do not adversely affect the use of water, even though the European communities directives suggest 10 mg/l K as guide level and 12 mg/l potassium as the maximum admissible concentration (Smeets and Amavis, 1981).

Potassium content of ground water is generally lower than surface water and soils. The background value in Uttar Pradesh water samples being less than 20 ppm on the average. However, at places surface water contain more than 20 ppm and soil water more than 30 ppm of potassium. Studies on K-contents of ground waters in Uttar Pradesh have revealed that in many cases the ground waters have anomalously high values for potassium, in absence of any

geological source of K-deposit in Uttar Pradesh. It is suggested that such high values owe their origin to unscientific use of K-fertilizers, coupled with falty water and crop management practices which allow applied K-fertilizers to be leached down to saturated zone (Handa, et al., 1983; Geol.,1983).

Total Annual Consumption :

Annual consumption of K-fertilizers in district Dehradun (Fig. 1) was 112 MT, 111 MT, 97 MT and 110 MT; in Saharanpur (Fig. 2) was 1849 MT, 1843 MT, 2167 MT and 2395 MT; in Muzaffarnagar (Fig. 3) was 1609 MT, 1862 MT, 2015 MT and 2289 MT; in Meerut (Fig. 4) was 1766 MT, 2342 MT, 2400 MT and 2597 MT; in Ghaziabad (Fig. 5) was 1365 MT, 1268 MT, 1335 MT and 1412 MT and in Bulandshahr was 2378 MT, 2400 MT, 3040 MT, and 3287 MT during 1979, 1980, 1981 and 1982 respectively (Table-V). In the study area the total annual consumption of K-fertilizers was 9079 MT, 9826 MT, 11054 MT and 12095 MT in four continuous years from 1978-79 to 1981-82, which reveals not much variation in the consumption of K-fertilizers during these years.

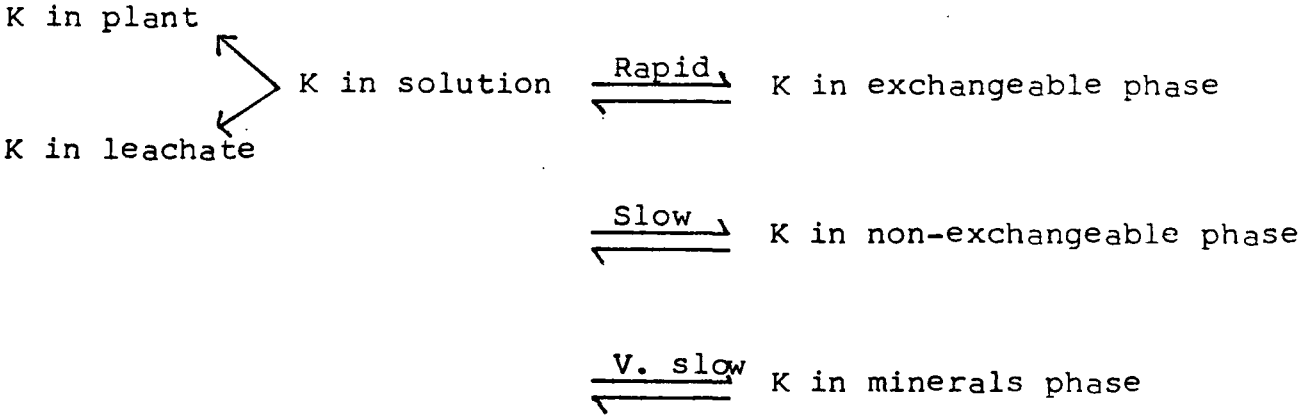
Source :

The main sources, both natural and anthropogenic, which contribute to the K-content of ground water are :(a) weathering of K-silicate

and other K-minerals present in the strata through which ground water is circulating; K-deposits etc. (b) contribution from rain water, including dry fall out (c) contributions from surface waters both indirectly, viz. seepage from canals as well as directly, viz. application of surface water from irrigation and their leaching the saturated zone as 'return irrigation flow' (d) plant residues and (e) application of plant nutrients containing K-ions, viz. compost gobar slurry, and K-fertilizers (Handa, et al., 1983).

Potassium Chemistry in Soil :

In soils K is supposed to exist in the following phases which are more or less in equilibrium as given below.



When K-fertilizer is added to soil, the concentration of K-ions in the soil solution rises rapidly. According to Olsen (1972) in normal soils the K-concentration in soil solution is in the range 10^{-4} to 10^{-5} molar, though on soils well supplied with K it may rise to 10^{-3} molar. However, it seems that this is an understatement, and K-content in soil solution may rise to much higher values. A portion of the added K may be taken up by the plant roots, a portion will get fixed in the soil and in consequence, unlike NO_3-ions it is not very mobile in soils containing much clay. Only potassium solution phase is susceptible to uptake by plant roots to leaching in a soil profile. The non-exchangeable phase generally represents slowly available forms of potassium and account for little clay and other types of integrate minerals. The mineral phase is however considered stable.

Health Hazard :

Excessive use of K-fertilizer causes several adverse health hazards. Potassium at low concentrations is harmless to the human system but very high concentrations viz. over 2000 mg K/l may be harmful to human nervous and digestive systems.

Prevention :

Since movement of K occurs in the aqueous phase, it is obvious that water management practices can play an important role in preventing pollution of ground water from this source. The application of correct dose of potassium fertilizer after 'Tissue Test' to know the potassium requirement of crops can go a long way in preventing excessive use of K-fertilizers, as compared to the adhoc addition of K-fertilizers, as suggested by potash India (Table-II). Crop rotation practice which envisages growing of deep rooted crops after a shallow rooted crop (e.g. growing of maize after potatoes) can assist in the recovery of K-leached down to the lower parts of the root zones, in contrast with the growing shallow rooted crops after a shallow rooted crop (potatoes after ground nuts or vice versa). The depth to water table and texture of the soils must also be taken into consideration as leaching of plant nutrients would be more feasible on light soils than on heavy soils and contamination will be more if the water table is high. Broadcast application of fertilizers on light soils may be more wasteful of fertilizer than 'band placement' near the seeds. Thus better water management practices coupled with proper utilization of fertilizer and avoidance of excessive use of fertilizers can lessen the contamination of ground water, surface water and soils, without affecting the crop yields. The ideal dose of K-fertilizer is 40 kg/hectare.

PESTICIDES :

Pesticides are also significant in agricultural areas because as they serve diffuse source of ground water pollution. The presence of these materials in ground water, even in minute concentrations, may have serious consequences in relation to potability of water. The impact of pesticides on ground water quality depends on the properties of the pesticides residue, rainfall or irrigation rates, and soil characteristics (Todd and McNulty, 1976). Most pesticides are relatively insoluble in water, while others are readily adsorbed by soil particles or are subject to microbial degradation. Pesticides, as a general class, are being employed extensively over the past few years for various purposes and have helped tremendously to make our lives more comfortable and healthy. Many objections have been raised from time to time regarding the danger of pesticides to flora and fauna, either due to indiscriminate application or of their toxic nature (Basargekar and Balaji, 1983). Pesticides pose a menancing threat to the well being of the poor in the third world countries because of their free availability, lack of adequate protection, improper storage, excessive and wasteful use leading to environmental pollution and absence of safety warnings apart from residues finding their way into food. Pollution of our environment is a problem of vital importance and widespread use of synthetic pesticides has raised some serious doubts in the minds of the public.

How much of a hazard do pesticides, already pose a great problem to the Third World. Exact figures are not available but estimates indicate a problem of considerable magnitude. In 1972, the WHO's expert committee on insecticides estimated that there were about 500,000 cases of the accidental pesticide poisoning in the world annually and about one per cent of these cases resulted in the death in countries "where medical treatment and antidotes are readily available" (which means the developed countries).According to conservative estimate, the total number of death every year would be around 9200.

DDT and other pesticides are likely to come into raw water to be used for treatment and supply as potable water. Discharge from the Hindustan Insecticides Factory manufacturing DDT at Delhi caused destruction of fish in Yamuna river according to Government of India's report, ICAR (1976). DDT and aldrin are highly toxic to man, fish and birds.

A number of pesticides are used in India and demand for them is on increase. During the last ten years, the use of DDT alone in India has increased nearly four folds. It is estimated that DDT and BHC requirements during 1985-86 would be about twenty thousand tonnes and ten thousand tonnes respectively, twice the present requirement.

Total Annual Consumption :

Table-VI reveals the Annual consumption of various pesticides, insecticides, herbicides, fungicides and rodenticides in district Dehradun was 52167 kg, 61213 kg, 67239 kg, 69008 kg and 70935 kg; in Saharanpur was 951129 kg, 972297 kg, 1000121 kg, 1400039 kg, and 1691116 kg; in Muzaffarnagar was 877798 kg, 1017791 kg, 1800729 kg, 2911218 kg and 301926 kg; in Meerut was 188187 kg, 2387372 kg, 3792129 kg, 4123191 kg and 5987761 kg; in Bulandshahr was 197962 kg, 1009267 kg, 1500197 kg, 1797271 kg, and 2506921 kg, and in Ghaziabad was 997500 kg, 1500971 kg, 180932 kg, 2509761 kg, and 3100934 kg, respectively in five continuous years from 1977-78 to 1981-82. Table-VI also reveals that consumption is increasing every year in each district of study area. Total annual consumption of various pesticides was 13660.58 tonnes in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr. This indiscriminate consumption of pesticides is causing pollutional hazard in area.

Sources :

Pesticides move in environment in many ways. They may occur as droplets from spraying operation, volatilization of compounds from soils and plants, burning material containing residues and their movement in air may occur in vapour phase or absorbed on

dust particles which are generally affected by meteorological conditions. Pulses, vegetables, foodstuffs, fruits, oil seeds, oil and other animal products like milk, egg, fish, meat, etc. contain a high amount of pesticide residues. Pesticides may enter aquatic ecosystem indirectly by drift and by spraying on agricultural land from fall out from air dust particle accumulation in the atmosphere, in run-off from agricultural lands by direct application to aquatic environment to eradicate mosquitoes, etc., by discharge of industrial waste emanating from pesticide factory (Nammalwar, 1984).

Nature of Pesticides :

The pesticide industry provides various formulations which are intended to control unwanted pests, weed or pathogens and manipulate plant growth. Depending on end usage they are accordingly classified as insecticides, fungicides, herbicides, rodneticides, molluscicides, nematocides, etc. Essentially they are chlorinated hydrocarbons, organo phosphates or sulphonates and in smaller quantities inorganic compounds (Table-III). There are two groups of synthetic pesticides : (i) organochlorine pesticides such as DDT and BHC which are most toxic to fish, (ii) organophosphate pesticides such as malathion and parathion, generally less toxic to fish. The common ones are listed in the Table-IV.

Effect of Pesticides on Animal and Mankind :

In fact, in India the per hectare use of pesticides is only about 180 gm against 18490 gm in U.S.A., 1870 gm in Europe and 10790 gm in Japan. In 104 samples of human body fat of normal Indian natives analysed by Dale, et al. (1965), DDT, BHC and dieldrin were detected. The mean level of DDT and its metabolites, BHC and dieldrin ranged between 13 to 30, 0.86 to 1.7 and 0.03 to 0.06 ppm, respectively.

DDT was introduced since 1944 for the control of typhus, malaria, yellow fever and other water borne diseases. Prolonged absorption of the toxic doses of organochlorine pesticide can cause change in liver, kidney and other organs. Compared with DDT the aldrin is approximately six times as toxic and dieldrin three times. Acute and sub-acute human intoxications have been reported from each of the organochlorine pesticides. A single dose of 10 mg of DDT will cause illness. In children, 25 mg of aldrin will cause, death, while the symptoms of acute toxicity in adults appear at level of 70 mg.

Some pesticides, including chlordane, endrin and heptachlor, still used in third world countries, are also highly toxic to earthworms which play an important role in circulating and aerating the soil.

Prevention :

The increasing usage of pesticides in our predominantly agricultural economy makes it necessary for us in India to adopt satisfactory methods for the disposal of their waste and lesser consumption of pesticides. The disposal practices followed till now have been found to be inadequate and also environmentally unsafe which makes incineration as the best present and future solution for this problem. Not only does it provide a total solution for destruction of these wastes but also offers additional advantage like energy savings and recovery of valuable chemicals. Incineration has also been adopted by world renowned European companies like Bayer, Ciba, BASF, Rhone-Poulenc for satisfactory disposal of wastes from their various plants (Basargekar and Balaji, 1983).

In aqueous system, pesticides encounter volatilization, decomposition by ultraviolet light radiation, microbial degradation, biological magnification and absorption and desorption from suspended matter. All these phenomena are not sufficient to result in self-purification of water. So above described additional treatment and disposal methods are required to eradicate pesticides from aquatic environment (Nammalwar, 1984).

CONCLUSION :

On the whole the consumption of N-fertilizer is greater as compared to consumption of P and K-fertilizers. Total annual consumption of all these fertilizers was 171139 MT, 170500 MT, 197428 MT and 230035 MT, in the years 1978-79, 1979-80, 1980-81 and 1981-82 respectively in all these districts. In all, 230.035 thousand metric tonnes of fertilizers were used during the year 1981-82, for the production of 30 lac metric tonnes of food grains in Kharif and Rabi crops which appears to be quite high. This indiscriminate consumpetion of nutrients together with agricultural wastes results in severe pollutional hazard in the soils and various water bodies in the study area.

Table-I : Characteristics of various forms of N, in natural waters.

Species	Processes participated
N_2	Biological and abiological nitrogen fixation and denitrification.
NH_3/NH_4	Ammonia-fixation, leaching and run-off, decomposition of organic matter, dry and wet deposition, fertilizer consumption, troposphere reactions, plant uptake, volatilization.
N_2O	Denitrification, reactions in the stratosphere.
No	Dry deposition reactions in atmosphere, combustion.
NO_2	Nitrate reductions in acid soils, atmosphere reactions combustion processes.
HNO_3/NO_2	Nitrification/denitrification processes, dry and wet deposition, leaching, run-off, atmospheric reactions.
NO_3	Nitrification, reactions in atmosphere.
Organic Nitrogen	Production of biomass, dry and wet deposition, volatilization and decomposition of organic nitrogen matter.

Table-II : Recommended dose of Potassic Fertilizers for various crops (Potash India).

Crop	K_2O Kg/acre			Crop	K_2O Kg/acre		
	Basal	Top-I	Top-II		Basal	Top-I	Top
Rice (HYV)	20-30	10-30	10-30	Wheat (HYV)	20-40	10-20	
Jowar (HYV)	10-30	15-25	-	Groundnut	20-30	-	
Cotton	10-20	10-20	-	Potatoes	20-30	20-30	
Sugarcane	-	40-60	40-60	Banana	105	225	

Table-III : Classification of Pesticides

Chemical Nature	Pesticides
1. Chlorinated Hydrocarbons	Aldrin, chlordane, BHC, DDT, Dieldrin, Heptachlor, Lindane, Toxaphene, Endrin, etc.
2. Organic Phosphates	Malathion, Parathion (Methyl), Parathion (Ethyl), Guthion, etc.
3. Miscellaneous Organic Compounds	2, 4-D, 2, 5-T, Carbaryl, Organic mercurials, Methyl bromide, etc.
4. Inorganic Compounds	Copper sulphate, Nickel chloride, $Pb_2As_2O_7$, etc.

Table-IV : Hazardous Compounds

Type of Pesticide	Hazardous Compound
1. Aldrin	Aldrin
2. Methylene Chloride	Methyl chloride, Methylene chloride, chloroform, carbon tetra chloride, perchloro ethylene.
3. Parathion and Methyl Parathion	Paranitrophenol, parathion sulphur, Hydrogen chloride, sodium carbonate.
4. Malathion	Trimethyl di thiophosphate, Diethyl-maleate, malathion contaminated solvents.
5. Chlorotoulene	Benzyl chloride, Benzotrichloride.
6. Phenoxy Herbicides	Chlorophenoxy compounds dichlorophenol (DCP), Acetic acid.
7. D.D.T.	Chlorobenzene, chloral, DDT, Spent acids (Hydrogen chloride, sulphuric acid).

Table-V : Districtwise Fertilizer Input in Metric Tonnes.

Name of District	1978-79				1979-80			
	Nitrogen	Phosphorus	Potassium	Total	Nitrogen	Phosphours	Potassium	Total
Dehradun	1144	268	112	1524	1182	336	111	1629
Saharanpur	28773	5684	1849	36306	27387	6599	1843	35829
Muzaffarnagar	27489	5055	1609	34153	27346	4986	1862	34194
Meerut	32383	6505	1766	40654	34087	7244	2342	43673
Ghaziabad	17943	3735	1365	23043	15867	3238	1268	20373
Bulandshahr	26516	6565	2378	35459	26647	5755	2400	34802
Total	134248	27812	9079	171139	132516	28158	9826	17050

... contd.

Name of District	1980-81				1981-82			
	Nitrogen	Phosphorus	Potassium	Total	Nitrogen	Phosphorus	Potassium	Total
Dehradun	1224	305	97	1626	1250	350	110	1710
Saharanpur	32278	7162	2167	41607	36278	7811	2395	46484
Muzaffarnagar	31209	5697	2015	38921	37409	6912	2289	46608
Meerut	40239	7311	2400	49950	48116	7510	2597	58223
Ghaziabad	16149	3992	1335	21476	17889	4719	1412	24020
Bulandshahr	33499	7309	3040	43848	39878	9809	3287	52973
Total	154598	31776	11054	197428	180820	37120	12095	23003

Table-VI : Districtwise Pesticide Input in Kilograms.

Name of District	1977-78	1978-79	1979-80	1980-81	1981-82
Dehradun	52167	61213	67239	69008	70935
Saharanpur	951129	972297	1000121	1400039	1691116
Muzaffarnagar	877798	1017791	1800729	2911218	301926
Meerut	188187	2387372	3792129	4123191	5987761
Bulandshahr	197962	1009267	1500197	1797271	2506921
Ghaziabad	997500	1500971	180932	2509761	3100934
Total	3264743	6948911	8341347	12810488	13659593

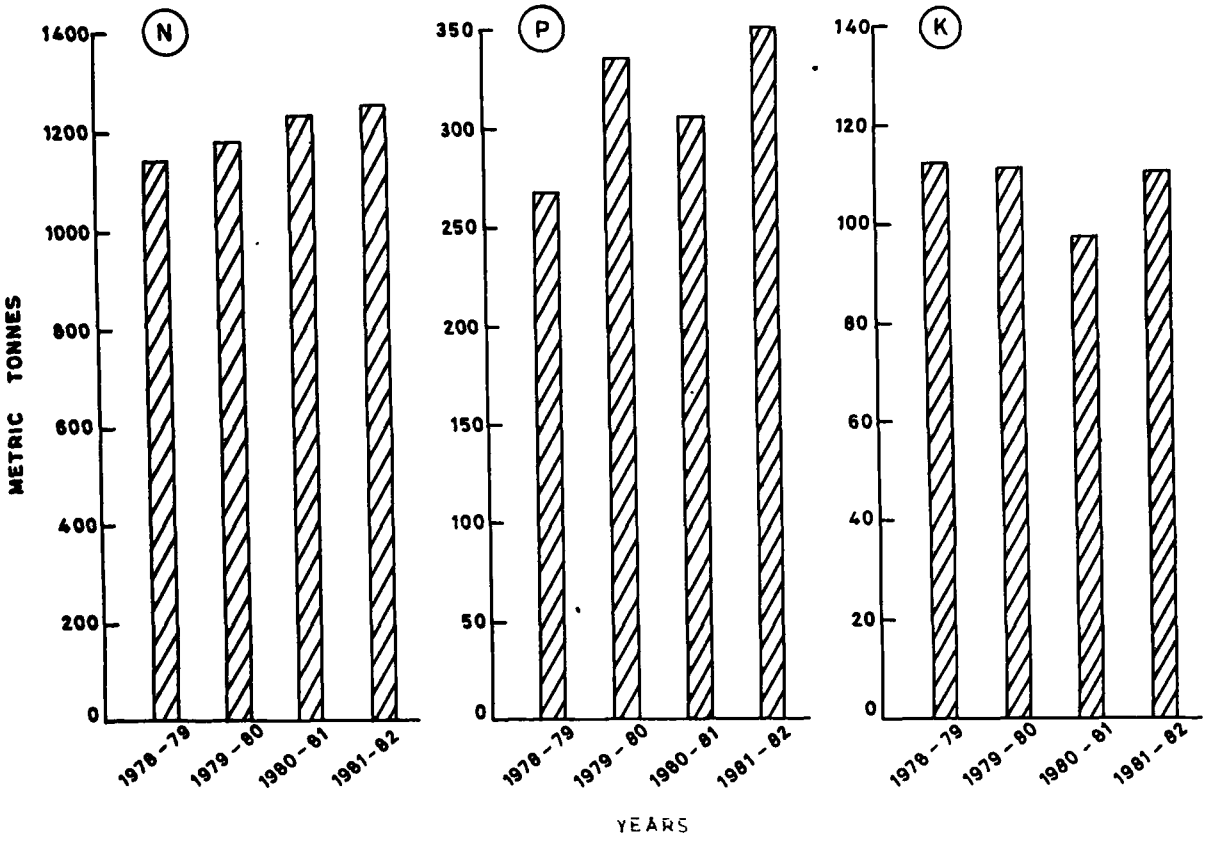


Fig. 1 BAR DIAGRAM REPRESENTS THE CONSUMPTION OF FERTILIZERS IN DEHRADUN

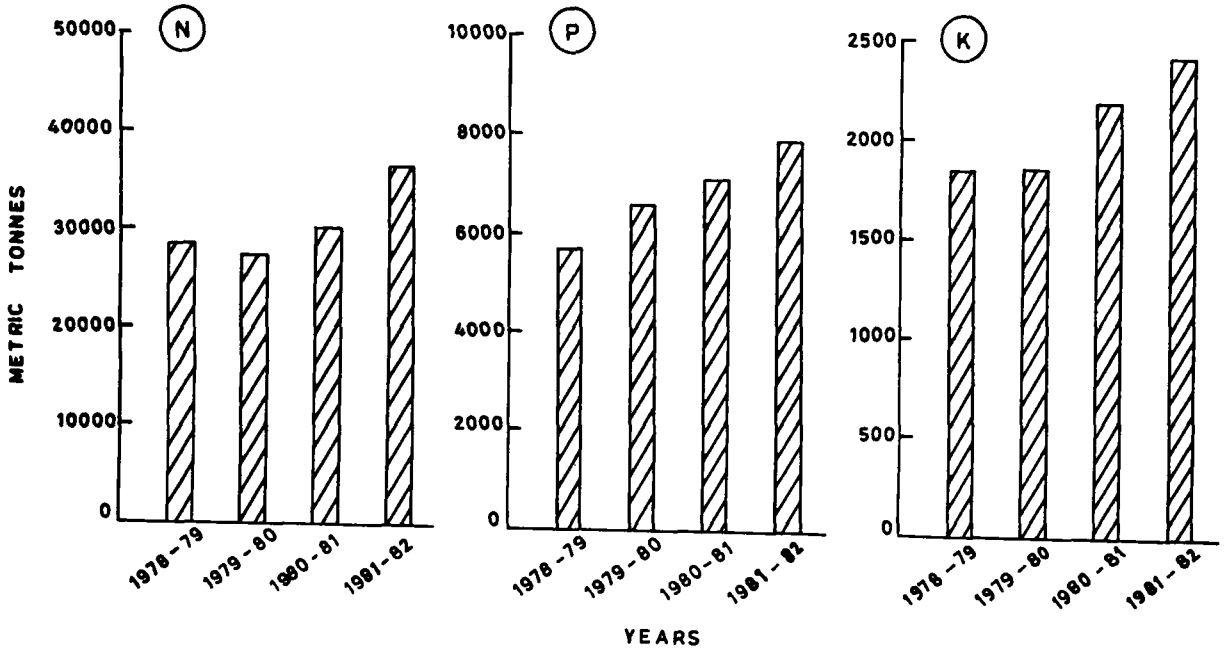


FIG. 2 BAR DIAGRAM REPRESENTS THE CONSUMPTION OF FERTILIZERS IN SAHARANPUR

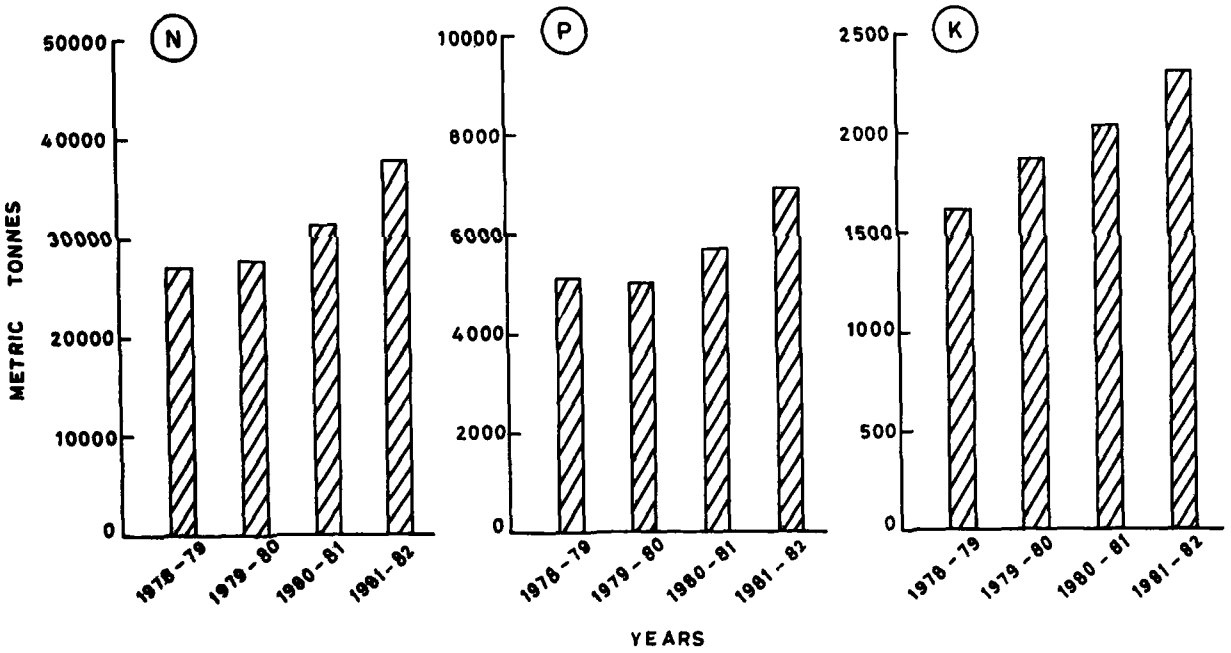


FIG. 3 BAR DIACRAM REPRESENTS THE CONSUMPTION OF FERTILIZERS IN MUZAFFARNAGAR

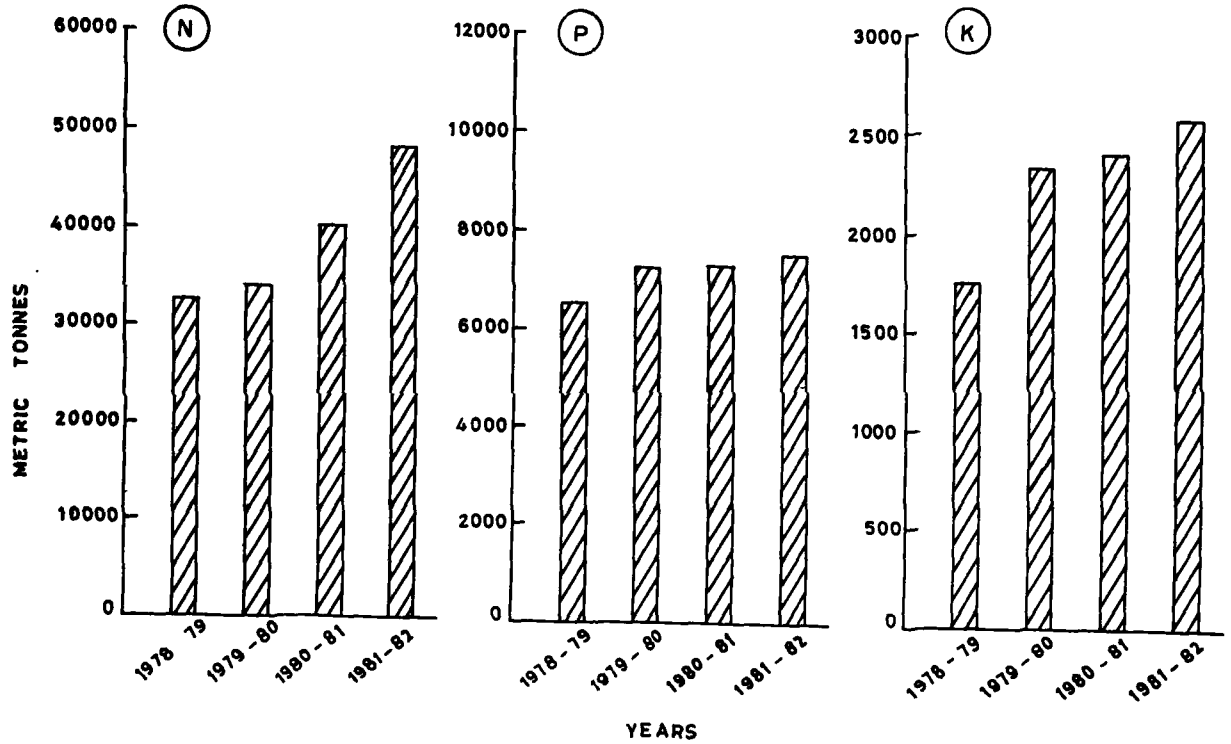


FIG. 4 BAR DIAGRAM REPRESENTS THE CONSUMPTION OF FERTILIZERS IN MEERUT

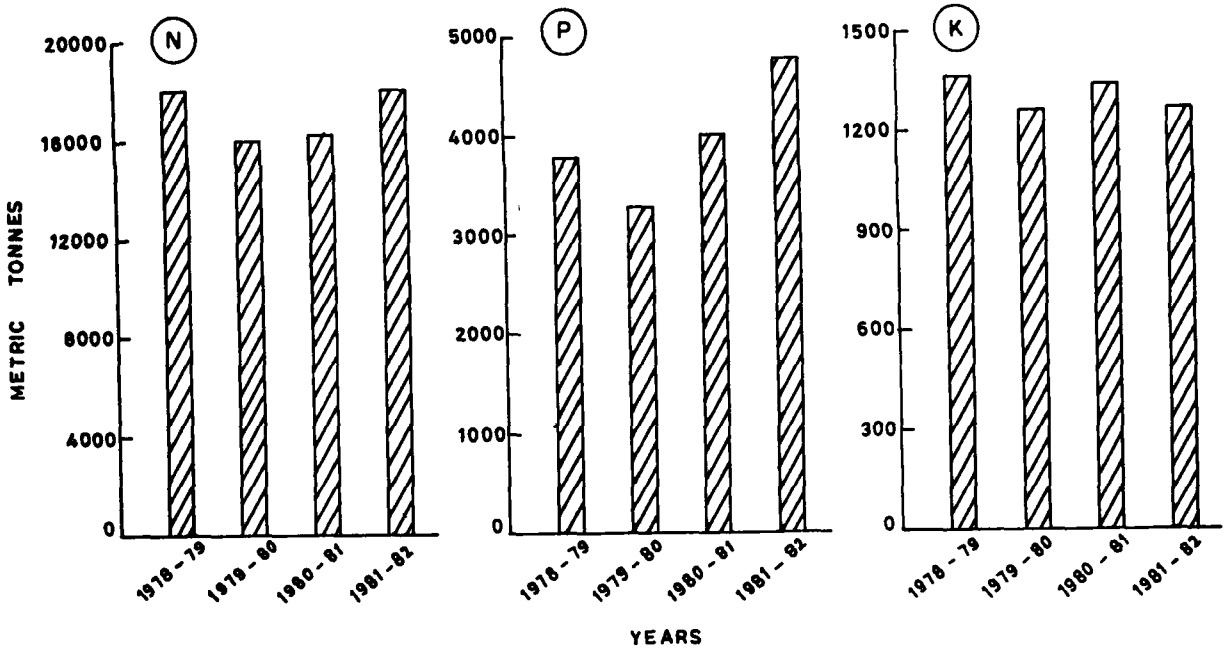


FIG. 5 BAR DIAGRAM REPRESENTS THE CONSUMPTION OF FERTILIZERS IN GHAZIABAD

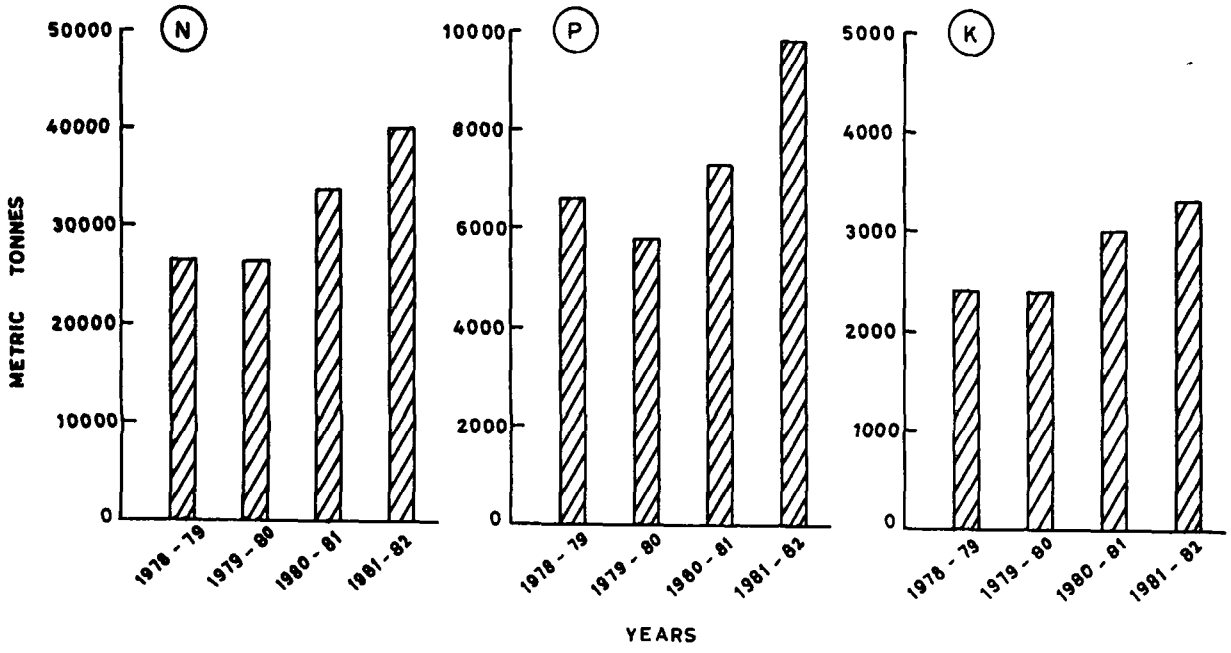


FIG. 6 BAR DIAGRAM REPRESENTS THE CONSUMPTION OF FERTILIZERS IN BULANDSHAHR

CHAPTER V

METHODS FOR WATER AND SOIL CHARACTERIZATION

CHAPTER-V

METHODS FOR WATER AND SOIL CHARACTERIZATION

SAMPLING LOCATIONS :

The main flowing rivers of western Uttar Pradesh are Yamuna, Ganga, Kali and Hindon. Water and soil samples were collected from and around the mid-stream of rivers at all sampling stations in Dehradun, Saharanpur, Muzaffarnagar, Meerut, Bulandshahr and Ghaziabad districts of western Uttar Pradesh. Near about 150 water and soil samples were collected in the month of April and May during the calender year 1983. Few samples were also collected from open wells and hand pumps. Person residing in these areas were mainly using river and well water for drinking and other purposes.

WATER SAMPLING PROCEDURE :

During the sampling programme informations regarding the rivers, irrigation and industries were collected. Polythene bottle of one litre capacity, soaked in acid, and rinsed with distilled water were used for the collection of water samples. Samples of water were collected by using a clean stainless steel water sampler which was introduced into the wells with the help of

rope and water taken out. Prior to transferring the water sample the bottle was rinsed thoroughly with the water to be sampled. A portion of sample was immediately filtered through Whatman filter paper no. 42 and acidified with 6N nitric acid (8 ml/l). The second portion of water was utilized for physico-chemical anlaysis without adding any preservative.

SOIL SAMPLING PROCEDURE :

All associated soil samples were collected in canvas bags of one kilogram capacity. A round nose trenching spade is a convenient tool for sampling surface soil. A soil tube is useful for small surface soil samples. Soil should be air dried before shipping or storing for any extended length of time. Air dry soils that contain deliquescent salt may accumulate enough moisture during short storage period to decompose a canvas bag. A container impervious to water vapour should be used for such soils. All samples should be air dried before storing into the container. The following suggestions are quite useful in the selection of soil samples.

1. Visible or suspected salt crusts on the soil surface should be sampled separately and the approximate depth of sample recorded

2. If the soil shows evidence of profile development or distinct stratification, samples should be taken from different horizons or layers.

3. In the absence of profile development or distinct stratification, surface samples including the surface crust should be taken to the plough depth, usually to a depth of 6 or 7 inches.

4. Sometime soil samples taken for salinity and alkali determinations may be composited to deduce the analytical work.

5. The size of sample will depend on measurement that are to be made.

METHODS OF ANALYSIS :

Water Samples :

All water samples were concentrated at low heat in laboratory. The water samples for common cations and trace metal contents (except Hg) were filtered through 0.45 μm membrane filters and 500 ml of the filtered sample were acidified with 10 ml concentrated HNO_3 (analytical grade HNO_3) before the concentration using evaporation method (Parker, 1972). The concentrated samples were analysed for trace metal concentration by atomic absorption spectrophotometer (Varian Techtron N525).

A blank sample was made, for each spectrophotometer analysis to account for any analytical and instrumental errors.

Soil Sediments :

All soil sediment samples for common cations and trace metal contents were air dried for 24 hour, grinded into sizes that passed through sieves no. 50 (opening size of 0.30 mm) and no. 100 (opening size of 0.15 mm), consecutively, and 3 gram of prepared sample were digested (refluxed) with 20 ml concentrated HNO_3 for 3 hours. The sample was then cooled, brought to 50 ml volume with 2% HNO_3 and the filtered solution analysed by atomic absorption spectrophotometer (Parker, 1972). For Hg analysis, 3 gm of the prepared sample were digested overnight in 200 ml volumetric flask with 25 ml Hg free concentrated HNO_3. The sample was then brought to 100 ml volume with deionized distilled water, added with 5 ml tin (II) chloride (10% in 10% HCl) and analysed for total Hg by same method.

Trace metals in the digested water and soil samples were analysed by digital atomic absorption spectrophotometer. Operating parameters were adjusted for optimum response. Various metals were determined by taking respective hollow cathode lamps and using their most intense resonance lines. Background correlation was used for lead and cadmium. A flame rich in acetylene was used for chromium.

The name of the different instruments/equipments and their respective use in water analysis laboratory are listed below (Das, 1983).

Name of the Instruments	Parameters Determined
1. pH meter	: pH of the water samples
2. Conductivity bridge	: Electrical conductivity of the water samples
3. Turbidimeter	: Turbidity of the water samples
4. D.O. meter	: Dissolved oxygen of the water body
5. Incubator, D.O. meter	: B.O.D.
6. Flame Photometer	: Alkali metals
7. Spectrophotometer (UV-VIS)	: Fe, Si, PO_4, NO_3, NO_2, NH_4, F, B, I, trace metals, etc.
8. Atomic absorption spectrophotmeter	: Almost all metals
9. Specific Ion Meter with electrodes	: F, Cl, Br, I, NO_3, CN, Eh, pH, metals and non-metals
10. Polaragraph	: Metallic Ions specially in trade effluents
11. Fluorimeter	: Fluorescent substances
12. Gas Chromatograph	: Dissolved gases, Pesticides, organic compounds, etc.
13. Total organic carbon analyser	: Organic carbon
14. Neutron Activation Analyser	: Analysis of trace quantity of pollutants
15. X-ray Fluorescence	: -do-
16. Mass Spectrometer	: Gas content of water, inorganic gasses, volatile inorganic impurities
17. Emission spectrography	: Semi-quantitative and quantitative determination of metals

pH DETERMINATION OF WATER :

pH of water is normally determined electrometrically using pH meter with glass and reference electrodes.

Reagents :

Buffer solutions of pH 4, 7 and 9 which may be prepared from the respective buffer tablets.

Procedure :

Connect the electrodes with the pH meter. It is then connected with mains and switch on the instrument for 10 minutes. Note the temperature of the buffer solution and set the instrument to that temperature. Standardise the instrument immersing the electrodes in the respective buffer solutions. Standardisation should be carried out either at pH 7 and 4 or pH 7 and 9 depending upon the acidic or alkaline character of water sample to be measured. Now remove buffer solution, wash electrodes with distilled water and finally with water whose pH is to be determined. Immerse the electrodes in the sample and measure the pH value. When the determinations are over, wash the electrodes thoroughly and keep them immersed in distilled water.

pH DETERMINATION OF SOIL :

Apparatus :

Container of 250 ml capacity or greater such as a cup of moisture box.

Procedure :

Prepare a saturated soil paste with distilled water and allow paste to stand at least one hour. Insert electrode into the prepared paste and raise and lower repeatedly until a presentative pH reading is obtained.

ATOMIC ABSORPTION SPECTROPHOTOMETER :

Sodium, potassium magnesium, calcium, iron, copper, manganese, zinc, cadmium, chromium, lead, nickel and cobalt were determined by atomic absorption spectrophotometer (Perkin Elmer Model 372). All metal contents were determined in filtered and acidified water and soil samples. Various metal contents were determined by taking hollow cathode lamps.

Atomic absorption spectrophotometer is almost similar to flame emission photometer in which water sample is sprayed into air-acetylene flame in order to excite the spectral lines of desired

element. Flame photometer, however, measures the amount of light emitted, whereas, in digital atomic absorption spectrophotometer a light beam is directed through the flame into a monochromator, onto a detector that measures the amount of light absorbed. In many instances absorption is more sensitive because it depends upon the presence of free unexcited atoms and generally the ratio of unexcited to excited atoms at a given moment is very high. As the wave length of light beam is characteristic of only the metal being determined, the light energy absorbed by the flame is a measure of concenctration of the metal in the sample.

Simplicity, sensitivity, specificity and other numerous advantages have caused this instrument to be adopted as a standard analytical method for routine determination of major and minor trace metals in waters and soil sediments. However, chemical interference gives some trouble in atomic absorption spectrophotometer which may be caused by lack of absorption of metal atoms bound in molecular combination in the flame phenomenon. The chemical interference may occur when the flame is not sufficiently hot to dissociate the molecule, as the case of phosphate interference with magnesium. Addition of lanthanum will overcome the phosphate interference in magnesium, calcium and barium determinations.

Apparatus :

Atomic Absorption Spectrophotometer :

Atomic absorption instrument having a source of energy, an atomizer burner system, a monochromator and a detector.

Glass ware :

All glass wares should be washed with detergent, rinsed with hydrochloric acid (HCl), tap water and deionised distilled water simultaneously.

Burner :

The burner recommended by particular instrument manufacturer should be used. Nitrous oxide burner is required for some trace elements.

Analytical Procedure :

According to metal concentration, select the hollow cathode lamps for chemical analyses, the lamp should be allowed to warm minimum fifteen minutes. Now set the position of monochromator at the correct wave length, select proper monochromator slit

width, and adjust the hollow cathode. Simultaneously adjust the burner and nebulizer flow rate for maximum per cent absorption and stability and balance photometer, light the flame and regulate the flow of fuel and oxidant. Run a series of standards of metals under chemical analysis. Computerized values of metal concentration are printed on paper sheet automatically. Therefore, it is important to run standards each time for a sample or series of samples.

Concentration of all trace metals has been calculated in milligram/litre or parts per million (ppm) in water and soil samples by using the following formula.

$$\text{Mg/l} = \frac{\text{Sample absorbance X concentration of standard}}{\text{standard absorbance}}$$

Scope and Application of Instrument :

1. The method is simple, rapid and applicable to a large number of metals in surface water, ground water, domestic and industrial wastes, saline and alkali soils. Metal contents are readily determined by atomic absorption spectrophotometer.

2. Detection limit, sensitivity and optimum range of the metals will vary with various models of atomic absorption spectrophotometers. Concentration shown below may be extended much lower with

scale expansion and conversely extended upwards by using a less sensitive wave length. Detection limit may also be extended through the concentration of the sample or through solvent extraction techniques.

Optimum concentration range, sensitivity,detection limit and various instrumental parameters for determination of sodium, potassium, calcium, magnesium, iron, copper, zinc, nickel, cobalt, lead, manganese, chromium and cadmium are given below.

SODIUM :

Optimum concentration range : 1.0 - 200 mg/l

Sensitivity - 0.003 mg/l

Detection limit - 0.001 mg/l

Preparation of Standard Solution :

Stock solution - Dissolve 2.542 gm of NaCl, dried at 140°C, in distilled water and make up to one litre. One ml equals one mg of sodium (1000 mg/l).

Instrumental Parameters :

1. Sodium hollow cathode lamp
2. Wave length - 3302 Å

3. Type of burner - Boiling

4. Fuel - Acetylene

5. Oxidant - Air

6. Type of flame - Oxidizing

7. Photomultiplier tube - IP-28.

POTASSIUM :

Optimum concentration range - 0.01 - 2 mg/l

Sensitivity - 0.01 mg/l

Detection limit - 0.005 mg/l

Preparation of Standard Solution :

1. Stock solution - Dissolve 0.1907 gm of KCl, dried at 110°C, in distilled water and make up to one litre. One ml equals 0.10 mg of potassium (100 mg/l).

2. Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis.

Instrumental Parameters :

1. Potassium hollow cathode lamp

2. Wave length - 7665 Å

3. Type of burner - Boiling

4. Fuel - Acetylene

5. Oxidant - Air

6. Type of flame - Slightly oxidizing

7. Photomultiplier tube - IP-21.

CALCIUM :

Optimum concentration range - 1.0-200 mg/l

Sensitivity - 0.07 mg/l

Detection limit - 0.003 mg/l

Preparation of Standard Solution :

1. Stock solution - Suspend 1.250 gm of $CaCO_3$ (analytical reagent grade), dried at 180°C for one hour before weighing, and dissolve cautiously with a minimum of dilute HCl. Dilute to 100 ml with distilled water. One ml.equals 0.5 mg of calcium (500 mg/l).

2. Lanthanum chloride solution - Dissolve 29 gm of La_2O_3, slowly in 250 mg concentrated HCl and dilute to 500 ml with distilled water.

3. Prepare dilutions of stock calcium solutions to be used as calibration standards at the time of analysis. To each calibration

standard solution add 1.0 ml of $LaCl_3$ solution for each 10 ml of volume of working standard, i.e. 20 ml working standard + 2 ml $LaCl_3$ = 22 ml.

Instrumental Parameters :

1. Calcium hollow cathode lamp
2. Wave length - 4227 Å
3. Type of burner - Boiling
4. Fuel - Acetylene
5. Oxidant - Air
6. Type of flame - Reducing
7. Photomultiplier tube - IP-28.

MAGNESIUM :

Optimum concentration range - 0.01-2 mg/l
Sensitivity - 0.005 mg/l
Detection limit - 0.005 mg/l

Preparation of Standard Solution :

1. Stock solution - Dissolve 0.829 gm of magnesium oxide, (analytical reagent grade) in the 10 ml of double distilled HNO_3 and dilute to one litre with distilled water. One ml equals 0.50 mg of magnesium.

2. Lanthanum chloride solution - Dissolve 29 gm of La_2O_3, slowly in 250 ml concentrated HCl and dilute to 500 ml with distilled water.

3. Prepare dilutions of stock magnesium solution to be used as calibration standards at the time of analysis. To each calibration standard solution, add 1.0 ml of $LaCl_3$ solution for each 10 ml of volume of working standard i.e. 20 ml working standard + 2ml $LaCl_3$ = 22 ml.

Instrumental Parameters :

1. Magnesium hollow cathode lamp
2. Wave length - 2852 Å
3. Type of burner - Boiling
4. Fuel - Acetylene
5. Oxidant - Air
6. Type of flame - Reducing
7. Photomultiplier tube - IP-28.

IRON :

Optimum concentration range - 0.1-20 mg/l

Sensitivity - 0.006 mg/l

Detection limit - 0.004 mg/l

Preparation of Standard Solution :

1. Stock solution - Carefully weighed 1.0 mg of pure iron wire (analytical reagent grade) and dissolve in 5 ml redistilled HNO_3, warm if necessary, when solution is complete, make up to one litre with distilled water. One ml equals to 1 mg Fe (1000 mg/l).

2. Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. Maintain an acid strength of 0.15% nitric acid in all calibration standards.

Instrumental Parameters :

1. Iron hollow cathode lamp
2. Wave length - 2483 Å
3. Type of burner - Boiling
4. Fuel - Acetylene
5. Oxidant - Air
6. Type of flame - Oxidizing
7. Photomultiplier tube - IP-28

COPPER :

Optimum concentration range -0.1-10 mg/l

Sensitivity -0.04 mg/l

Detection limit - 0.005 mg/l.

Preparation of Standard Solution :

1. Stock solution - Carefully weighed 1.0 gm of electrolytic copper. Dissolve in 5 ml redistilled HNO_3 and make up to one litre with distilled water. Final concentration is one mg of Cu per ml (1000 mg/l).

2. Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. Maintain an acid strength of 0.15% nitric acid in all calibration standards.

Instrumental Parameters :

1. Copper hollow cathode lamp
2. Wave length - 3247 $\mathring{A}$
3. Type of burner - Boiling
4. Fuel - Acetylene
5. Oxidant - Air
6. Type of flame - oxidizing
7. Photomultiplier - IP-28.

ZINC :

Optimum concentration range - 0.1-2 mg/l
Sensitivity - 0.02 mg/l
Detection limit - 0.005 mg/l.

Preparation of Standard Solution :

1. Stock solution - Carefully weighed 1.0 gm of analytical reagent grade zinc metal and dissolve cautiously in 10 ml HNO_3. When solution is complete, make up to one litre with distilled water. One ml equals to one mg of Zn (1000 mg/litre).

2. Prepare dilutions of stock solution to be used as calibration standards at the time of analysis. Maintain an acid strength of 0.15 HNO_3 in all calibration standards.

Instrumental Parameters :

1. Zinc hollow cathode lamp
2. Wave length - 2139 $\mathring{A}$
3. Type of burner - Boiling
4. Oxidant - Air
5. Type of flame - Oxidizing
6. Photomultiplier tube - IP-28.

LEAD :

Optimum concentration range - 1-10 mg/l
Sensitivity - 0.06 mg/l
Detection limit - 0.01 mg/l.

Preparation of Standard Solution :

1. Stock solution - Carefully weighed 1.599 gm of analytical reagent grade lead nitrate $Pb(NO_3)_2$ and dissolve in distilled water. When solution is complete, acidify with 10 ml redistilled HNO_3 and dilute to one litre with distilled water. One ml equals 1 mg Pb (1000 mg/l).

2. Prepare dilution of stock solution to be used in calibration at the time of analysis. Maintain an acid strength of 0.15% nitric acid in all calibration standards.

Instrumental Parameter :

1. Lead hollow cathode lamp
2. Wave length - 2170 Å
3. Type of burner - Boiling
4. Fuel - Acetylene
5. Oxidant - Air
6. Type of flame - Slightly oxidizing
7. Photomultiplier - IP-28.

MANGANESE :

Optimum concentration range - 1-20 mg/l

Sensitivity - 0.04 mg/l

Detection limit - 0.005 mg/l.

Preparation of Standard Solution :

1. Stock solution - Carefully weighed 1.583 gm of analytical reagent grade manganese dioxide and dissolved in 10 ml of HCl. When solution is complete, dilute to one litre with distilled water. One ml equals 1 mg Mn (1000 mg/l).

2. Prepare dilutions of stock solution to be used as calibration standards at the time of analysis. Always maintain an acid strength of 0.15% nitric acid in all calibration standards.

Instrument Parameters :

1. Manganese hollow cathode
2. Wave length - 2795 Å
3. Type of burner - Boiling
4. Fuel - Acetylene
5. Oxidant - Air
6. Type of flame - Oxidizing
7. Photomultiplier tube - IP-28.

CHROMIUM :

Optimum concentration range - 1.0-200 mg/l

Sensitivity - 0.02 mg/l

Detection limit - 0.01 mg/l.

Preparation of Standard Solution :

1. Stock solution - Dissolve 1.923 gm of chromium trioxide (reagent grade) in distilled water. When solution is complete, acidify with redistilled nitric acid and dilute to one litre with distilled water. One ml equals one mg of chromium.

2. Prepare dilutions of stock solution to be used as calibration standards at the time of analysis. Always maintain an acid strength of 0.15% nitric acid in all calibration standards.

Instrument Parameters :

1. Chromium hollow cathode lamp
2. Wave length - 3579 Å
3. Type of burner - Boiling
4. Fuel - Acetylene
5. Oxidant - Air
6. Type of flame - Slightly fuel rich
7. Photomultiplier tube - IP-28.

CADMIUM :

Optimum concentration range - 0.1-1 mg/l

Sensitivity - 0.004 mg/l

Detection limit - 0.001 mg/l.

Preparation of Standard Solution :

1. Stock solution - Carefully weighed 1.142 gm of cadmium oxide (analytical reagent grade) and dissolved in 5 ml redistilled HNO_3. Dilute to one litre distilled water. One ml equals 1 mg Cd.

2. Prepare dilutions of stock solution to be used as calibration standards at the time of analysis. Maintain an acid strength of 0.15% nitric acid at all calibration standards.

Instrumental Parameters :

1. Cadmium hollow cathode lamp
2. Wave length - 2288 Å
3. Type of burner - Boiling
4. Fuel - Acetylene
5. Oxidant - Air
6. Type of flame - Oxidizing
7. Photomultiplier tube - IP-28.

CHAPTER VI

ENVIRONMENTAL QUALITY OF WATER

CHAPTER-VI

ENVIRONMENTAL QUALITY OF WATER

INTRODUCTION :

Groundwater is not chemically pure. The relative slow movement of water percolating through rocks affords an intimate long contact of water with minerals. These minerals are soluble and form dissolved salts. Ordinary higher proportion of dissolved salts are present in ground water than in surface water. Excess irrigation water percolating to the water table may contribute substantial quantities of salt. Water passing through the root zone of cultivated areas usually contains saline concentration several times that of the applied irrigation water. In addition, soluble soil materials, fertilizers, and selective absorption of salts by plants will modify salt concentration of percolating waters. Factors governing the increase include soil permeability, drainage facilities, amount of water applied, crops and climate. Thus, high salinities are found in soils and groundwaters of arid climates where leaching by rain water is not effective in diluting the salt solutions. Similarly poor drained areas, contain high salt concentrations.

Calcium, magnesium, potassium and sodium are major constituents of water and soils. These dissolved ions affect the quality of ground water and soil, as acidic, neutral, alkaline or saline water, which in turn affect the quality of ground water used for irrigation, domestic and industrial purposes. The quality required for a ground water supply depends upon its purpose; thus needs for drinking water, industrial water and irrigation water vary widely. In specifying the quality of water, measures of chemical, physical and bacterial constituents are important, depending upon the purpose for which it is utilized. Recommended limits of water quality can be determined, serving as guides for protection and development of ground water and soil water.

In general, the study of quality of water is important for the following purposes.

1. To know the geochemistry of ground water and soil (source of salts).

2. To know the suitability of ground water for various uses and for possible treatment if the quality of ground water is not suitable for given purpose.

EXPRESSION OF WATER ANALYSIS :

Various units are commonly employed in expressing the data obtained from chemical analysis of water and soil samples which are listed as follows.

1. Weight Per Weight Units :

The most common units is parts per million (ppm), which represents one part by weight of dissolved matter in a million parts of weight of solution such as one milligram of solute in one kilogram of solution. It is a dimensionless unit and parts per million and milligram per litre are numerically almost the same if the concentration of dissolved solids is low and specific gravity of water is nearly one.

2. Equivalent Weight Units :

As cations and anions combine in a fixed ratio, this method takes into account, not only the weight concentration of ions but also the concept of ions and chemical equivalence. The common unit is equivalents per million (epm) or more exactly milligram/equivalents per kilogram. Equivalents per million is calculated by dividing parts per million by equivalent weight of ion. In present work the values are expressed in terms of parts per million and equivalent per million.

Present chapter deals with the quality limits of water supplies for domestic uses, industrial and irrigation purposes. From the study point of view, description has been divided into three parts.

1. Quality of irrigation water
2. Quality of water in relation to domestic use
3. Quality of water in relation to formations

QUALITY OF IRRIGATION WATER :

The concentration and composition of dissolved constituents in water determine its quality for irrigation use. Quality of water is an important consideration in any appraisal of salinity or alkali conditions in an irrigated area, because effects of salts on soils, causing changes in soil structure, permeability and aeration, indirectly affect plant growth. The characteristics of an irrigation water that appear to be most important in determining its quality are -

1. Total concentration of soluble salts
2. Relative proportion of sodium to other cations
3. Concentration of Boron or other elements that may be toxic
4. Bicarbonate concentration as related to concentration of calcium plus magnesium (Eaton, 1950), under some conditions only.

1. Total Dissolve Solids (TDS) :

If the salt concentration in water increases, it is difficult to the plants to extract water.

2. According to U.S. Salinity Laboratory Staff (1950), the irrigation water is classified to determine -

i. Salinity hazards

ii. Sodium hazards

i. Salinity Hazards :

Water in the range of 450 to 1500 TDS in ppm, can be used for irrigation under good management and if concentration of salts is very high, there will be toxic effect of certain salts to the plants. Four classes of irrigation water based on TDS, are shown in the Table-I.

ii. Sodium Hazards :

Soluble inorganic constituents of irrigation water react with soils as ions rather than as molecules. The principal cations are calcium, magnesium and sodium, with small quantities of potassium ordinarily present. The principal anions are carbonate, bicarbonate, sulphate and chloride with fluoride and nitrate occurring in low concentrations. The alkali hazard involved in the use of water for irrigation is determined by absolute and relative concentrations. If the proportion of sodium is high, the alkali hazard is high; and conversely, if calcium and magnesium predominate, the hazard is low. Alkali soils are formed

by accumulation of exchangeable sodium and are often characterized by poor tilth and low permeability. High concentration of sodium relative to calcium and magnesium in irrigation waters adversely affect the soil structure. The cations in the soil solution, become fixed on the surface of clay particles. When high sodium water is applied to soil, the number of sodium ions, combined with the soil increases while an equivalent quantity of calcium, or other ions, is displaced. Sodium tends to deflocculate and effects porosity and permeability of the soil or causing deflocculation and reduction of permeability and porosity. In an opposite case where calcium is dominant cation, the exchange occurs in the reverse direction, creating a flocculated and more permeable soil. The addition of gypsum ($CaSO_4$) to soil results in the improvement of soil texture and drainability through base exchange process.

The adverse effect on soil caused by the high concentration of sodium is known as sodium hazard. Index used for predicting the sodium hazard of irrigation water is the concentration of sodium and proportion of sodium to calcium and magnesium, which is known as sodium adsorption ratio (SAR) as proposed by U.S. Agriculture Development may be defined by the equation -

$$SAR = \frac{Na}{\sqrt{(Ca + Mg) / 2}}$$

where Na, Ca and Mg are in epm per litre (milli-equivalent per litre). Sodium adsorption ratio of soil solution is simply related to adsorption of sodium by soil; consequently, this ratio has certain advantages for use as an index of sodium or alkali hazard of water.

The concentration of soil solution is increased by extraction of water from soil by root and by evaporation. As the quantity of salt adsorbed by plants is relatively small, the salts remained in the soil are more concentrated than the applied irrigation water. In next irrigation this more concentrated solution may be displaced downward or diluted, and so the concentration of solution in contact with the soil varies with time and location in the profile. It is not unusual to find shallow ground water or drainage water that is from 2 to 10 times concentrated than the irrigation water. It is reasonable to assume, however, that for a limited depth of soil, such as the top 12 inches, the concentration of the soil solution is not, on the average, more than 2 or 3 times the concentration of irrigation water. Under conditions, in the soil where it is permissible to neglect precipitation and absorption of soluble salts by roots, it is clear that irrigation water, after entering the soil, becomes more concentrated without change in its relative composition, i.e. the soluble sodium percentage does not change. THE SAR value, however, increases in proportion to the square root of

total concentration, i.e. if the concentration is doubled the SAR value increases by a factor of 1.41, if the concentration is quadrupled the SAR value will be doubled. It has been observed that where an irrigation water of relatively constant composition is used and drainage conditions are good, the ESP (Exchangeable-sodium-percentage) value of soil varies only slightly from season to season or year to year. This implies that the cation-exchange material of the soil has reached a steady state relative to cations in the soil solution which are derived from irrigation.

Classification of Irrigation Water : Classification of irrigation waters with respect to SAR (Table-II) is based primarily on the effect of exchangeable sodium and physical conditions of soil. Sodium sensitive plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration in the physical condition of soil. Four classes of irrigation water according to SAR values are given below.

Low Sodium Water (S_1) : Low sodium water (Fig. 1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium sensitive crops such as stone fruit trees may accumulate injurious concentration of sodium.

Medium Sodium Water (S_2) : Medium sodium water (Fig. 1) may bé cause appreciable sodium hazard in fine textured soils having high cation-exchange capacity, specially under low leaching conditions, unless gypsum ($CaSO_4$) is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

High Sodium Water (S_3) : High sodium water (Fig. 1) may produce harmful levels of exchangeable sodium in moist soils and will require special soil management - good drainage, high leaching and organic matter additions. Gypsiferrous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for the replacement of exchangeable sodium, except that amendments may not be feasible with waters of high salinity.

Very High Sodium Water (S_4) : Very high sodium water (Fig. 1) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity. Use of gypsum or other amendments may make the use of these waters feasible. Sometimes the irrigation water may dissolve sufficient calcium from calcareous soils to decrease the sodium hazard appreciably and this would be taken into account in the use of class-S_3 and class-S_4 waters. For calcareous soils with high pH values or for non-calcareous soils, the sodium status of water in classes S_3 and S_4 may be improved by addition of gypsum to water.

Similarly it may be beneficial to add gypsum to soil periodically when class-S_3 and class-S_2 waters are used.

3. Concentration of Boron :

Among sixteen important micronutrients, element boron, is an essential plant nutirent for its normal growth, in very small quantity, but in larger concentrations it becomes toxic. If it is present in very small amount or exceeds certain limits in irrigation water, it may cause injury to the plant. Normally, 0.5 mg/l of boron is essential even for sensitive crops, but if water contains boron more than 4.0 mg/l, it is harmful for all types of crops. Quantities needed vary with crop type; sensitive crops require minimum amounts whereas tolerant crops will make maximum growth at several times of these concentrations (Table-III).

As per FWPCF (1968), maximum concentration of boron, one ppm in irrigation water is recommended whereas Ayers and Branson (1975) suggest, continuous use of irrigation water containing 0.75 mg/l boron. For short time use, maximum 2 mg/l boron may be applied in fine textural soils.

Boron toxicity occurs in limited, scattered areas in arid or semi-arid regions. While its incidence is not restricted to saline or alkali soils. Excess of boron is frequently present in saline soils.

4. Bicarbonate concentration as Related Concentration of Calcium plus Magnesium (Eaton, 1950) :

When some of the carbonates and bicarbonates are in excess of calcium and magnesium, there is almost a complete precipitation of the later.

Residual carbonate (RC) = $(CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$

QUALITY OF WATER IN RELATION TO DOMESTIC USE :

1. Water Standards :

Quality limits of water supplied for drinking and irrigation purposes, established by various organizations, namely, WHO (Table-IV), USEPA (Table-V), Water Pollution Prevention Board (Table-VI), U.S. Public Health (Table-VII) and ISI, ICMR and NTAC (Table-VII).

2. Bacterial Quality :

Most pathogenic bacteria found in water are indigenous to intestinal tract of animal and man. So water should be free from harmful coliform bacteria. Coliform test results are reported as the most probable number (MPN) of coliform group orgnaisms in a given volume of water. The mean concentration

of the total coliform organisms in river water shows considerable seasonal variation (Table-VI).

QUALITY OF WATER IN RELATION TO FORMATIONS :

Donalt E. White etc. (1963) have given that -

(a) Ratios of Ca/Na/Mg/Ca are generally high in basic igneous rocks. The source of salts is mainly from ferromagnesium minerals and plagioclase feldspar.

(b) Sedimentary rocks, particularly sandstones, whill have the ratios of Ca/Na, HCO_3/Cl, SO_4/Cl are commonly higher than water from igneous rocks and generally TDS are also higher.

(c) In case of alluvium, the nature of concentration depends upon the source rock, i.e. the alluvium is being derived from igneous or from sedimentary source rocks.

In general, the waters in alluvium derived from igneous rocks will have low total dissolved salts, compared to the alluvium derived from sedimentary rocks, but the climatic conditions, nature of irrigation, organic contents may give rise to very high concentration of total dissolved solids with chlorides and sulphates.

Table-I : Based on the TDS the water is divided into 4 classes.

S.No.	Class	Salinity	TDS and Salinity
1.	C_1	Low salinity water	Up to 150 ppm and suitable for most crops. Specific conductivity - 250 µs/cm.
2.	C_2	Medium salinity water	Salt between 150 to 450 ppm can be used in most cases. Specific conductivity - 250-750 µs/cm.
3.	C_3	High salinity water	Salt between 450 to 1500 ppm. Specific conductivity - 750-2250 µs/cm.
4.	C_4	Very high salinity water	Salts more than 1500 ppm suitable for irrigation under ordinary condition. Specific conductivity - more than 2250 µs/cm.

µs/cm = Microsiemens/cm = Micromhos/cm

Table-II : Classification of irrigation water (U.S. Salinity Board).

S. No.	Class	SAR ratio	Sodium content	Suitability
1.	S_1	0-10	Low sodium	Excellent water suitable for all crops in all soils
2.	S_2	10-18	Medium sodium	Good water with slight sodium hazard
3.	S_3	18-26	High sodium	Fair water. Producing harmful effect and require special management of soil, such as leaching
4.	S_4	>26	Very high sodium	Poor water. Generally unsuitable for irrigation

Table-III : Permissible limits of Boron to several classes of irrigation water (after Wilcox, 1955).

Water class	Percent sodium	Specific conductance µs/cm	BORON, ppm		
			Sensitive crops	Semitolerant crops	Tolerant crops
Excellent	<20	<250	<0.33	<0.67	<1.00
Good	20-40	250-750	0.33-0.67	0.67-1.33	1.00-2.00
Permissible	40-60	750-2000	0.67-1.00	1.33-2.00	2.00-3.00
Doubtful	60-80	2000-3000	1.00-1.25	2.00-2.50	3.00-3.75
Unsuitable	>80	>3000	>1.25	>2.50	>3.75

Table-IV : World Health Organisation Standards for Potable Water (1971).

Characteristics	Permissible ppm	Excessive ppm
Total solids	500	1500
Colour	5 Hazen unit	50 Hazen unit
Turbidity	5 Jackson unit	25 Jackson unit
Iron	0.3	1.0
Chloride	200	600
Manganese	0.1	0.5
Copper	1.0	1.5
Zinc	5.0	15
Calcium	75	200
Magnesium	50	150
Lead	-	0.1
Chromium	-	0.05
Selenium	-	0.05
Arsenic	-	0.2
Cyanide	-	0.01
(Mg + Na) SO_4	500	1000
Nitrate	45	-
Phenols	0.001	0.002
pH value	7-8.5	6.5 or 9.2

Table-V : United States Environmental Protection Agency Proposed Criteria For Water Quality used for Irrigation, Livestock, Public Water Supply.

Characteristics	Irrigation ppm	Livestock ppm	Public supply ppm
Cadmium	0.01 0.05 (20 yrs.)	-	0.01
Chromium	0.1 1.0 (20 yrs.)	1.0	0.05
Copper	0.20	0.5	1.00
Lead	5.0 10.0 (20 yrs.)	0.1	0.05
Manganese	0.2 10.0 (20 yrs.)	no limit	0.05
Nickel	0.20 2.0 (20 yrs.)	-	-
Sodium	no limit	-	-
Zinc	-	25	5
Chloride	no limit	-	250
Hardness	-	-	no limit
Dissolved oxygen	-	-	no limit
pH	4.5 - 9.0	-	5.0 - 9.0

Table-VI : Water Quality Criteria for the various designated best uses.

Classification	Parameters affecting the stated use	Quality criteria proposed
A. Drinking water source without conventional treatment but after disinfection	1. Coliform MPN	Less than 50/100 ml
	2. Turbidity	Less than 10 units
	3. Colour	Less than 10 units
	4. BOD	Less than 2 ppm
	5. DO	More than 6 ppm
	6. Toxicants	No acute toxicity
	7. Plate count	Less than 50/100 ml
	8. Floating matter	Not noticeable
	9. Taste and odour	Not perceptible
B. Bathing, swimming and Recreation	1. Coliform MPN	Less than 500/100 ml
	2. Turbidity	Less than 25 units
	3. Colour	Less than 10 units
	4. BOD	Less than 3 ppm
	5. DO	More than 5 ppm
	6. Toxicants	No acute toxicity
	7. Floating matter	Not noticeable
	8. Taste and odour	Not perceptible
C. Drinking water source after conventional treatment	1. Coliform MPN	Less than 5000/100 ml
	2. Colour	Less than 25 units
	3. BOD	Less than 3 ppm
	4. DO	More than 4 ppm
	5. Toxicants	No acute toxicity
D. Propagation of wildlife, fisheries, etc.	1. Coliform MPN	Less than 5000/100 ml
	2. BOD	Less than 6 ppm
	3. DO	More than 4 ppm
	4. Toxicants	No acute toxicity
	5. Temperature	Range - 5-25°C
E. Irrigation, industrial cooling and controlling waste disposal	1. TDS	Less than 1000 ppm
	2. (Ca + Mg)	Less than 100 ppm
	3. Sodium ratio	Less than 0.5
	4. Chlorides	Less than 250 ppm
	5. Boron	Less than 2.0 ppm

Central Board for Prevention and Control of Water Pollution

Table-VII : U.S. Public Health Drinking Water Standards

Chemical characteristics	Upper limit, ppm
Lead	0.1
Fluoride	1.5
Arsenic	0.05
Selenium	0.05
Chromium	0.05
Copper	3.0
Fe + Mn	0.30
Magnesium	125
Zinc	15
Chloride	250
Sulphate	250
Phenols	0.001
Total solids (desirable)	500
Total solids (permitted)	1000

Table-VIII : ISI, ICMR and NTAC Water Quality Criteria for Public Water Supply.

Characteristics	ISI ppm	ICMR ppm	NTAC ppm
Coliform	Less than 5000/100 ml	-	-
Cadmium	-	0.01	0.01
Chloride	600	-	250
Lead	0.1	0.01	0.05
Manganese	-	-	0.05
Chromium	0.05	-	0.05
Zinc	-	-	5.0
Copper	-	-	1.0
Arsenic	0.2	0.05	0.05
Nitrate	5	-	-
Mercury	-	0.001	-
Cyanide	-	0.05	-
pH	6-9	-	6-8.5

ISI - Indian Standard Institution

ICMR - Indian Council of Medical Research

NTAC - National Technical Advisory Committee.

CHAPTER VII

COMMON CATION POLLUTION

CHAPTER-VII

COMMON CATION POLLUTION

INTRODUCTION :

The area under study lies in upper Ganga-Yamuna doab, covering the most fertile part of Ganga basin which constitute the agricultural bowl of northern India, besides enormous industrial development during recent years. These industries include sugar factories, textile and paper mills, refractories and various chemical factories, which releases various types of wastes on soils and surface water bodies. The agricultural sources such as irrigation return flows, animal wastes, drain to surface channels, further aggravate the pollution problem in this region, besides the excessive inputs of fertilizers and pesticides for augmenting the production, a portion of which usually leaches through the soil and to the underground water. Soil amendments are also applied to irrigated lands to alter the physical and chemical properties of the soils. Lime, gypsum and sulphur are widely used for this purpose; substantial amount of these soil amendments may eventually leach to the groundwater, thereby increasing its salinity.

Sodium, potassium, calcium and magnesium are commonly known cations in waters, groundwaters and associated soil sediments. Durum, et al. (1960); Miller (1961); Anderson and George (1966); noticed 39 ± 5.9 ppm sodium content in river waters. Feldspars, clay minerals, evaporites, halite and industrial wastes are some of the main sources of sodium contents which is generally less than 200 mg/l whereas in sea water and brines it is around 1000 mg/l and 25000 mg/l respectively. The potassium content in river waters and soil sediments, is derived from feldspars, feldspathoids, some mica, clay minerals, etc. It is generally less than 10 mg/l which goes up to 100 mg/l in hot springs, and 25000 mg/l in brines. Moderate quantities of potassium do not adversely affect the use of water, even though the European Communities directives suggest 10 mg/l K as guide level and 12 mg/l K as the maximum admissible concentration. Potassium is slightly less common than sodium in igneous rocks and its contents in groundwater is also smaller than of sodium because of very different behaviour of these two alkali metals in natural system. Sodium tends to remain in solution while potassium is liberated with greater difficulty from silicate minerals. The potassium content of groundwater is generally below 10 mg/l and seldom reaches 20 mg/l.

Calcium is a common constituent of natural waters, resulting from dissolution of amphiboles, feldspars, gypsum, pyroxenes, aragonite, calcite, dolomite, clay minerals and super-phosphate fertilizers.

It is generally found to be less than 100 mg/l; whereas brines may contain as high as 75000 mg/l. Magnesium, on the other hand, is derived from amphiboles, olivine, pyroxenes, dolomite, magnesite and clay minerals which contain less than 50 mg/l, whereas ocean waters, it is as high as 1000 mg/l, and in brines it may go up to 57000 mg/l. Magnesium concentration in river waters however varies from 10 ppm to 50 ppm (Livingstone, 1963).

COLLECTION OF SAMPLES :

At most of the sampling stations two sampling points were established along both sides of the river, one at the upstream, i.e. just before entering the city and the other at the down-stream i.e. just after leaving the city, following the established sampling norms as discussed earlier.

RESULTS AND DISCUSSION :

The concentration of common cations i.e. sodium, potassium, calcium and magnesium in different river waters, groundwater and associated soil sediment samples at different sampling stations have been presented in Table-I. The results of chemical analysis show variation, average concentrations, correlation of common cations in river waters, groundwater and associated soil sediment samples. pH variation and sodium adsorption ratios (SAR) have also been determined for all these samples.

Yamuna River :

Sodium :

Maximum concentration of sodium in river water (97.04 ppm) and associated soil sediment samples (32.15 ppm) is found at Delhi Yamuna bridge and Bulandshahr respectively, whereas minimum concentration of 2.02 and 9.99 ppm is noticed in Saharanpur and Bulandshahr respectively. Figures 1, 2, 9 and 10 show the variation of sodium concentration in water and associated soil sediment samples.

Average concentration of sodium (Figs. 17 and 21) water and associated soil sediment samples along both sides of river (Table-IV) is noticed as follows.

Side-A : R.W. (60.19), R.S. (16.17)
Side-B : R.W. (37.59), R.S. (20.67)

Water samples of side-A have higher average concentration of Na than side-B because at the Yamuna bridge side-A, is much closer to many of the chemical and allied industries. Water samples of both sides have higher average concentration of Na as compared to soil samples due to its high mobility.

R.W. = River Water

R.S. = River Soil

Total average concentration of sodium (Figs. 25 and 26) in river water and associated soil sediment samples is 48.8 and 18.4 ppm respectively (Table-V).

It therefore reveals that domestic and industrial effluents in Delhi near Yamuna bridge and the large tract of alkali and saline soils in Bulandshahr district might be responsible for exceedingly high content of Na in water and soil samples of this part of the river basin. Water and soil samples collected at Rampur (Saharanpur) and Jewar (Bulandshahr) have minimum concentration ranges of Na, because of the fact that both these localities are agriculturally most productive and are situated away from the industries which discharges alkaline wastes.

Potassium :

Maximum concentration of potassium in water and associated soil sediment samples was noticed to be 15.27 and 13.43 ppm at Baghpat in Meerut and Bulandshahr, whereas minimum 0.16 and 1.72 ppm at Rampur (Saharanpur) and Dankaur (Ghaziabad) respectively. Figures 1, 2, 9 and 10 show the variation of potassium concentration in water and associated soil sediment samples.

Average concentration range of potassium (Figs. 17 and 21) in river water and associated soil sediment samples (Table-IV) along both the sides of river bank is noticed as follows.

Side-A : R.W. (6.9), R.S. (4.89)

Side-B : R.W. (7.26), R.S. (6.56)

There is not much variation in concentration ranges of K in water and soil samples of both sides of the Yamuna river.

Total average concentration of potassium (Figs. 25 and 26) throughout the course of Yamuna river water and associated soil sediment samples in the study area (Table-V) comes to 7 and 5.7 ppm respectively.

The high values of K in this part of the study area owe their origin due to indiscriminate consumption of K-fertilizers to boost the agricultural production in the districts of Meerut and Bulandshshar, the excess of which gets its way in the various surface water bodies through irrigation run-off. Minimum content of K is obtained at Rampur (Saharanpur) and Dankaur (Ghaziabad) because both these localities are quite far from industrial belt and on the contrary, this area is agriculturally well developed and posses most fertile soil in this region.

Calcium :

Maximum concentration range of calcium in Yamuna river water and associated soil sediment samples (426.7 and 28.03 ppm) is

found in Muzaffarnagar and minimum 13.6 and 1.40 ppm at Saharanpur and Delhi Yamuna bridge respectively. The variation of calcium concentration in river water and associated soil sediment samples is shown in figures 1, 2, 9 and 10.

Average concentration of calcium (Figs. 17 and 21) in river water and associated soil sediment samples along both sides of river (Table-IV) is noticed as follows.

Side-A : R.W. (167.27), R.S. (14.88)
Side-B : R.W. (183.44), R.S. (10.93)

Side-B water samples have higher average concentration of Ca due to its closeness to industries as compared to side-A.

Total average concentration of calcium (Figs. 25 and 26) in river water and associated soil sediment samples (Table-V) is 175 and 12.6 ppm respectively.

These extremely high values of Ca may be mainly due to return irrigation flows, unscientific use of Ca-nutrients and clay minerals and kankars at shallow depth in water and soil samples collected from the district of Muzaffarnagar. Water samples collected from Rampur (Saharanpur) have minimum content of Ca which may be due to absence of industries and calcium poor, and productive soils in the region.

Magnesium :

Magnesium concentration in river water and associated soil sediment samples varies from 0.10 to 501.7 ppm and 0.76 to 40.79 ppm. The minimum concentration of Mg in river water (0.10 ppm) and soil sediment samples (0.76 ppm) was recorded at Chhaprauli (Meerut) and Kairana (Muzaffarnagar), whereas maximum (501.7 and 40.79 ppm) at Bulandshahr and Dankaur (Ghaziabad) respectively. Figures-1, 2, 9 and 10 reveal the variation of magnesium in the samples collected from this region.

Average concentration of magnesium (Figs. 17 and 21) in river water and associated soil sediment samples along both sides of river (Table-IV) is given as follows.

Side-A : R.W. (141.3), R.S. (19.74)
Side-B : R.W. (120.26), R.S. (19.64)

Side-A water samples of Yamuna have higher average content of Mg than side-B, it might be due to the presence of kankars vein on that side of the river bank.

Total average concentration of magnesium (Figs. 25 and 26) in river water and associated soil sediment samples (Table-V) comes out to be 130.70 and 19.50 ppm respectively.

Plant residue ash, thick reh deposits, dolomitic source rock and clay minerals may further contribute such an abnormally high content of Mg in water and associated soil samples in Bulandshahr district which is situateed in the downstreams of the rivers Ganges and Yamuna.

It is quite likely that return irrigation flows, unscientific use of K and Ca nutrients, alkali and saline soils and kankars etc. mighthave also been responsible for such an exceedingly high values of Na, K, Ca and Mg in river waters of the district Bulandshshar. Similarly minimum content of cations in water samples at Rampur (Saharanpur) which is situated in the upstream of the river might be due from non-accessibility of any pollutional hazard in that part of the basin.

Hindon River :

Sodium :

Maximum concentration range of sodium in river water (79.34 ppm) and associated soil sediment samples (19.99 ppm) was recorded in Saharanpur (near Star Paper Mill), and minimum of 15.77 and 10.49 ppm at Baghpat (Meerut) and Bhayla (Saharanpur) respectively. Figures-3, 4, 11 and 12 show the variation of sodium concentration in water and associated soil sediment samples.

Average concentration of sodium (Figs. 18 and 22) in water and associated soil sediment samples along both sides of river (Table-IV) comes to be as follows.

Side-A : R.W. (50.34), R.S. (15.07)

Side-B : R.W. (42.83), R.S. (17.03)

There is not much variation in concentration of Na in water and soil samples on the both sides. Water samples have higher content of Na as compared to soil samples.

Total average concentration of sodium (Figs. 25 and 26) in river water and associated soil sediment samples (Table-V) is noticed as 46.50 and 16.03 ppm respectively.

In Saharanpur district, the Hindon river is flowing through intensively cultivated area and in the close vicinity of paper and textile mills which discharge effluents and other waste products that have high content of Na to various water bodies in the district of Saharanpur. Whereas minimum concentration of Na is noticed at Baghpat (Meerut) and Bhayla (Saharanpur) because sodium tolerant crops such as sugarcane, cotton and barley are extensively grown in these localities which also make the soil deficient in sodium.

Potassium :

Maximum concentration of potassium in river water (17.09 ppm) and soil sediment samples (6.44 ppm) and minimum of 0.05 and 2.63 ppm was recorded near Star Paper Mills and Bhayla Road, both in Saharanpur district respectively (Figs. 3, 4, 11 and 12).

The average concentration of potassium (Figs. 18 and 22) in water and associated soil sediment samples (Table-IV) along both sides of river comes as follows.

Side-A : R.W. (6.60), R.S. (4.17)
Side-B : R.W. (8.64), R.S. (4.08)

There is not much variation in average content of K in water as well as soil sediments of Hindon river.

Total average concentration of potassium in river water and associated soil sediment samples (Figs. 25 and 26) is 7.6 and 4.12 ppm respectively (Table-V).

Star and Aggarwal Paper Mills and excessive use of K-nutrients to augment the agricultural produce are likely to contribute higher amount of K in water and soil bodies in the district of Saharanpur near Star Paper Mill, while minimum value is recorded at Bhayla (Saharanpur) which is far away from the industrial vicinity.

Calcium :

Calcium content in river water (Figs. 3 and 4) and associated soil sediment (Figs. 11 and 12) samples varies from 66.3 to 713.2 ppm and 0.55 to 26.68 ppm respectively. The maximum concentration of calcium in river water (713.2 ppm) and soil sediment (26.68 ppm) samples was recorded near Star Paper Mill in Saharanpur district and minimum (66.3 and 0.55 ppm) at Baghpat (Meerut) respectively.

Pulp and paper mills, increasing use of Ca-fertilizers and kankars at shallow depth contribute to such high values of Ca in river water samples collected near the Star Paper Mills in Saharanpur district. On the other hand, minimum content of Ca is found at Baghpat (Meerut) because of good quality of fertile soil free from alkali and saline patches and excessive cultivation of sugarcane which is also responsible for calcium replenishment from these soils.

The average concentration of calcium (Figs. 18 and 22) in water and associated soil sediment samples (Table-IV) along both sides of the river is given as follows.

Side-A : R.W. (297), R.S. (14.77)

Side-B : R.W. (301), R.S. (12.05)

There is little variation in average content of Ca in water and soil samples on both the sides due to some seasonal variations. Total average concentration of calcium in river water and associated soil sediment samples (Figs. 25 and 26) is 299.4 and 13.6 ppm respectively (Table-V).

Magnesium :

Maximum concentration of magnesium in river water (Figs. 3 and 4) and associated soil sediment (Figs. 11 and 12) samples of 171.1 and 31.25 ppm was noticed in Meerut and Muzaffarnagar and minimum of 0.11 and 0.19 ppm in Saharanpur and Ghaziabad city respectively.

The average concentration of magnesium (Figs. 18 and 22) in water and associated soil sediment samples (Table-IV) along both the sides of river is noticed as follows.

Side-A : R.W. (40.86), R.S. (16.23)
Side-B : R.W. (16.28), R.S. (14.97)

Average content of Mg of river on side-A is higher than side-B, which is possibly due from the presence of clayey concretions rich in Mg rather any other extraneous source.

Total average concentration of magnesium in river water and associated soil sediment samples in the area (Figs. 25 and 26) comes to 28.50 and 15.6 ppm respectively (Table-V).

Various industrial and domestic effluents, detergents and clay concretions rich in Mg are the prime sources of such high values of Mg in water and associated soil samples in district Meerut. Simultaneously, water samples collected at Maheshpur (Saharanpur) have minimum values of Mg because the paucity of any pollutional hazard in the locality.

Liquid waste effluents of paper and textile mills, indiscriminate consumption of K-fertilizers and kankar at shallow depth are some of the main sources which are responsible for the higher contents of Na, K, Ca and Mg in water and soil samples near Star Paper Mills in district Saharanpur and minimum content of cations at localities (Bhayla in Saharanpur district) due to their inaccessibility of any pollutional hazard and their location in the upstreams of the river.

Kali River :

Sodium :

Sodium content in river water (Figs. 5 and 6) varies from 20.27 to 92.65 ppm in Saharanpur and Meerut and in associated soil sediment samples (Figs. 13 and 14) varies in between 10.78 to 34.46 ppm in Muzaffarnagar and Bulandshahr districts respectively.

Average concentration of sodium (Figs. 19 and 23) in water and associated soil sediment samples (Table-IV) is as follows.

Side-A : R.W. (42.69), R.S. (19.69)
Side-B : R.W. (59.07), R.S. (18.75)

Side-B water of river Kali has slightly higher average value of Na than side-A, because the former is very close to the industries discharging various kinds of waste effluents regularly.

Total average concentration of sodium (Figs. 25 and 26) in river water and associated soil sediment samples (Table-V) comes out to be 50.8 and 19.2 ppm respectively.

Liquid waste effluents of paper and textile mills, large number of sugar factories and thick reh deposits are responsible to add high amounts of Na to river waters in Meerut and Bulandshahr districts. Minimum Na content at Bhagwanpur (Saharanpur) and Incholi village (Muzaffarnagar) because both localities are farther away from industries and located at the upstream of the river.

Potassium :

Potassium content in river water (Figs. 5 and 6) and associated soil sediment samples (Figs. 13 and 14) varies from 0.53 to 17.04

ppm and 2.4 to 15.95 ppm respectively. Maximum concentration of potassium in river water (17.04 ppm) and soil sediment samples (15.95 ppm) and minimum of 0.53 and 2.4 ppm was recorded in the districts of Bulandshahr and Muzaffarnagar respectively.

Average concentration of potassium (Figs. 19 and 23) in water and associated soil sediment samples (Table-IV) is noticed as follows.

Side-A : R.W. (7.20), R.S. (5.56)
Side-B : R.W. (6.88), R.S. (5.18)

Average K content in water and soil samples on both the sides varies slightly due to change in the flow regime.

Total average concentration of potassium in river water and associated soil sediment samples (Figs. 25 and 26) is 7.04 and 5.8 ppm respectively (Table-V).

Such high values of K in the downstream in Bulandshahr district are due mainly due to unscientific and excessive use of K-fertilizers which finally get its way into the river through nalas and other channels flowing in low lying cultivated area. Minimum concentration of K is found at Incholi village in district Muzaffarnagar becuase of its location which is away from industries and intensive farming practices with proper crop rotation pattern which is mainly due to its educated and well informed cultivators.

Calcium :

Maximum concentration (569.6 and 33.43 ppm) of calcium in river water and associated soil sediment samples is found in Meerut and Muzaffarnagar and minimum (42.8 and 0.20 ppm) in Bulandshahr and Saharanpur (Figs. 5, 6, 13 and 14) respectively.

The average concentration of calcium (Figs. 19 and 23) in water and associated soil sediment samples (Table-IV) along both sides of river bank is as follows.

Side-A : R.W. (261.81), R.S. (16.10)
Side-B : R.W. (289.03), R.S. (15.70)

Water samples of side-B have high average content of Ca than side-A because most of the sugar factories in region are situated on this side which regularly discharge their waste, the soil is alkaline and occasional lenses of kankar are present on that side of the river.

Total average concentration of calcium in river water and associated soil sediment samples (Figs. 25 and 26) comes to 275.4 and 15.90 ppm respectively (Table-V).

Significantly higher amounts of Ca in river waters is contributed by waste effluents of paper and textile mills, sugar factories and

calcium carbonate minerals and kankar at shallow depth at places in the districts of Meerut and Muzaffarnagar. Similarly water and soil samples collected from Bhagwanpur in the district of Saharanpur in the upstream of the river have minimum concentration of Ca because of the fact that there is no significant industry or any other major pollutional hazard in this locality.

Magnesium :

Maximum concentration of magnesium in river water (Figs. 5 and 6) and associated soil sediment (Figs. 13 and 14) samples is noticed as 348.3 and 50.01 ppm in Bulandshahr city and minimum 0.01 and 0.42 ppm in Saharanpur.

Average concentration of magnesium (Figs. 19 and 23) in water and associated soil sediment samples (Table-IV) along both sides of river is found as follows.

Side-A : R.W. (89.22), R.S. (15.09)
Side-B : R.W. (112.85),R.S. (20.16)

Water samples on side-B have a higher concentration of Mg than side-A. Because various sugar factories and other waste discharging industries are located on that side.

Total average concentration of magnesium in river water and associated soil sediment samples (Figs. 25 and 26) is noticed as 101.03 and 17.6 ppm respectively (Table-V).

Liquid waste effluents of sugar factories, thick reh deposits and clay minerals are the chief sources of high concentration of Mg in Bulandshahr district. Water samples collected from Bhagwanpur (Saharanpur) have minimum values of Mg because of the absence of any significant pollutional hazard.

Various waste effluents of paper and textile mills and large number of sugar factories and alkali and saline patches are likely source of the high contents of Na, K, Mg and Ca in river water and associated soil samples in Meerut and Bulandshahr districts whereas minimum content of these cations in water and soil samples is recorded at Incholi village (Muzaffarnagar)and Bhagwanpur (Saharanpur) because both these localities are situated in the upstream of the river and away from industries.

Ganga River :

Sodium :

Maximum concentration of sodium in river water (Figs. 7 and 8) and associated soil sediment (Figs. 15 and 16) samples is observed as 89.19 and 64.23 ppm and was recorded in Narora

(Bulandshahr) and Saharanpur and minimum 0.01 and 11.5 ppm in Rishikesh (Dehradun) respectively.

Average concentration of sodium (Figs. 20 and 24) in water and associated soil sediment samples (Table-IV) along both sides of river is given as follows.

Side-A : R.W. (45.74), R.S. (22.64)
Side-B : R.W. (49.95), R.S. (16.50)

Average content of Na in water and soil samples of both sides slightly varies due to the sinuous nature of flow regime of the river. Water samples have higher Na content than soil sediment samples.

Total average concentration in river water and associated soil sediment samples (Figs. 25 and 26) is 47.8 and 19.5 ppm respectively (Table-V).

Admixture of alkali and saline soils and industrial waste effluents tend to increase the higher amounts of Na in river water and associated soil sediment samples collected from the districts of Bulandshahr and Saharanpur. Minimum content of Na at Dehradun is due to the absence of alkali and saline soils and less developed industrialization.

Potassium :

Maximum concentration (14.15 and 31.6 ppm) of potassium in river water (Figs. 7 and 8) and associated soil sediment (Figs. 15 and 16) was found in districts of Bulandshahr and Saharanpur and minimum (0.20 and 1.77 ppm) in Rishikesh (Dehradun) respectively.

Average concentration of potassium (Figs. 20 and 24) in water and associated soil sediment samples (Table-IV) along both sides of river comes out to be as follows.

Side-A : R.W. (4.10), R.S. (8.30)
Side-B : R.W. (6.77), R.S. (4.81)

Water samples of side-B have higher average content of K than side-A. Because side-B is closer to industries and river also show meandering at places in this part of the basin.

Total average concentration of potassium in river water and associated soil sediment samples (Figs. 25 and 26) is 5.4 and 6.5 ppm respectively (Table-V).

Anthropogenic sources such as plant residues and increasing consumption of K-nutrients tend to contribute high contents of K in water and soils in the districts of Bulandshahr and

Saharanpur. On the other hand minimum content of K at Dehradun is due to absence of industrial activities and undulating topography, less cultivation and mineralogy of the source rocks, etc.

Calcium :

Calcium content in river water (Figs. 7 and 8) and associated soil sediment (Figs. 15 and 16) samples varies in between 13.4 to 818.5 ppm and 0.70 to 41.16 ppm respectively. Maximum content of Ca (818.5 and 41.16 ppm) in river water and associated soil samples and minimum (13.4 and 0.70 ppm) is recorded in the districts of Meerut and Dehradun respectively.

Average concentration of calcium (Figs. 20 and 24) in water and associated soil sediment samples (Table-IV) is given below.

Side-A : R.W. (285.91), R.S. (19.74)
Side-B : R.W. (207.28), R.S. (17.82)

Water samples of side-B have slightly higher average content of Ca than side-A. Because side-B is closer to industries and presence of occasional kankar lenses.

Total average concentration of calcium in river water and associated soil sediment samples (Figs. 25 and 26) comes out to be 246.5 and 18.7 ppm respectively (Table-V).

Large number of sugar factories, paper and textile mills, carbonate minerals and kankar lenses at shallow depth tend to increase the concentration levels of Ca in river waters in district Meerut.

Minimum value of Ca is reported in the samples collected in district Dehradun is mainly due to poor industrialization and absence of Ca-minerals at shallow depth in that part of the basin.

Magnesium :

Maximum magnesium content in river water (Figs. 7 and 8) and associated soil sediment (Figs. 15 and 16) samples of 245.6 and 78.03 ppm was noticed at Ramghat (Bulandshahr) and Raibala (Dehradun) and minimum of 0.04 and 0.69 ppm at Parikshitgarh (Meerut) and Hardwar (Dehradun) respectively.

Average concentration of magnesium (Figs. 20 and 24) in water and associated soil sediment samples (Table-IV) is given as follows.

Side-A : R.W. (73.41), R.S. (13.24)
Side-B : R.W. (63.01), R.S. (21.10)

Water and soil samples of side-B have higher average value of Mg than side-A, because side-B is much closer to various kinds of waste discharging industries.

Total average concentration in river water and associated soil sediment samples (Figs. 25 and 26) comes out to be 68.20 and 17.10 ppm respectively (Table-V).

It is suggested that value of Mg owe their origin due to anthropogenic activities. The high concentration of Mg in both the water and soil sediment samples in Bulandshahr and at Dehradun preferably owe their origin to the overwhelming amalgamation of various industries using Mg based raw materials or catalysts in the former and dolomitic limestone terrain in the latter. On the other hand minimum content of Mg at Hardwar is due to less industrialization and absence of alkali and saline soils and predominance of gravel and sandy beds in the region.

The high values of Na, K, Ca and Mg in Ganga river water and associated soils, may be attributed to the large number of paper and textile mills and sugar factories in Meerut district and increasing consumption of K-fertilizers, thick reh deposits and kankar at shallow depth in Saharanpur and Bulandshahr.

On the other hand water and soil samples collected at upstream points in the district of Dehradun have generally minimum content of cations which may possibly due to the absence of alkali and saline soils, forested and grassland topography and poor industrialization in the region.

Ground Water :

Sodium :

Sodium concentration ranges from 3.53 to 87.57 ppm in groundwater and 9.39 to 21.63 ppm in associated soil sediment samples (Fig. 27) respectively. Maximum concentration of Na in groundwater (87.57 ppm) and soil samples (21.63 ppm) is noticed in the districts of Bulandshahr and Muzaffarnagar and minimum of 3.53 and 9.39 ppm at Bulandshahr respectively.

Average concentration of sodium in groundwater and associated soil sediment samples (Fig. 28) is estimated to be 48 and 17.26 ppm respectively (Table-XVII).

Potassium :

Potassium content in groundwater and associated soil sediment samples (Fig. 27) varies in between 2.57 to 9.49 ppm and 1.35

to 8.4 ppm respectively. Maximum concentration of K in ground water (9.49 ppm) and soil samples (8.44 ppm) is noticed at Muzaffarnagar, whereas minimum of 2.57 and 1.35 ppm at Bulandshahr.

Average concentration of potassium is 7.0 and 5.2 ppm in ground water and associated soil sediment samples (Fig. 28) respectively (Table-xVII).

Calcium :

Concentration of calcium (Fig. 27) varies from 1.20 to 503.5 ppm and 0.24 to 23.95 ppm in groundwater and soil samples of study area respectively. Maximum content of calcium in groundwater (503.5 ppm) and soil samples (23.95 ppm) is recorded at Meerut, whereas minimum of 1.20 ppm and 0.24 ppm in the districts of Muzaffarnagar and Saharanpur respectively.

Average concentration of calcium is 167.7 ppm and 8.4 ppm in groundwater and soil sediment samples respectively (Table-XVII and Fig. 28).

Magnesium :

Minimum and maximum concentration of magnesium in groundwater (Fig. 27) was found to be 0.13 and 190.7 ppm in Muzaffarnagar city and Bulandshahr, whereas minimum and maximum concentration in associated soil sediment samples is 9.09 and 24.25 ppm, reported from Saharanpur and Meerut city respectively.

Average concentration of magnesium (Fig. 28) in groundwater and associated soil sediment samples comes to 33.6 and 14.5 ppm respectively (Table-XVII).

Average content of cations in groundwater (Na 48.0 ppm, K 7.0 ppm, Ca 167.7 ppm, and Mg 33.6 ppm) and soil samples (Na 17.26 ppm, K 5.2 ppm, Ca 8.4 ppm and Mg 14.5 ppm) is well within the range of permissible limits but Ca contents in Meerut district exceeds 503.5 ppm. It is thus obvious that such anomalously high values of Ca may be due to several anthropogenic sources mainly the sugar factories, paper and textile mills, unscientific use of Ca-fertilizers and kankar at shallow depth.

pH :

pH value varies in between 7 to 7.8, 7.2 to 7.8, 7.2 to 7.9 and 6.8 to 7.8 in Yamuna, Hindon, Kali and Ganga river water samples, whereas in associated soil sediment samples it varies from 7.0 to 7.3, 7.1 to 7.3, 7.1 to 7.4 and 7.2 to 7.6 respectively (Table-I, Figs. 29 and 30). The pH value in groundwater and associated soil sediment samples (Table-I) varies in between 6.5 to 7.8 and 7.1 to 7.3 respectively (Fig. 31). All the river waters maintain slightly acidic to alkaline pH at most of the sampling sites and ranged in between 7.8 ± 0.05 to 8.0 ± 0.15, whereas in soil sediment samples it is around 7.6 ± 0.05. Maximum (7.9) and minimum (6.8) pH in river waters were noticed at

Meerut and Dehradun districts respectively. Comparatively river water samples have higher pH than associated soil sediment samples. Maximum and minimum pH value in ground water and soil samples were obtained in Saharanpur and Bulandshahr districts respectively. Generally, surface water samples are more acidic than groundwater samples indicating their contamination by the host rocks.

Sodium Adsorption Ratio :

Sodium adsorption ratio (SAR) of Yamuna river water and associated soil samples (Fig. 32) ranges from 0.30 to 0.87 and 0.53 to 2.3 respectively (Table-XII). Maximum concentration in water and associated soil samples was noticed at Meerut and Delhi Yamuna bridge (2.3) and minimum at Bulandshahr (0.30) districts.

Sodium adsorption ratio of Hindon river water and associated soil sediment samples (Fig. 32) varies from 0.46 to 0.86 and 0.61 to 0.89 respectively (Table-XIII). Maximum (0.89) concentration in water and associated soil sediment samples was obtained at Delhi Yamuna bridge and Saharanpur and minimum at Meerut (0.46) respectively.

The sodium adsorption ratio of Kali-nadi water and associated soil sediment samples (Fig. 33) varies in between 0.51 to 0.95 and 0.53 to 0.98 respectively (Table-XIV). Maximum (0.98) concentration was noticed at Muzaffarnagar and minimum at Saharanpur (0.51).

SAR value varies from 0.10 to 1.48 and 0.55 to 1.79 in Ganga river water and associated soil samples (Table-XV, Fig. 33) respectively. Maximum concentration in water and soil samples is noticed at Saharanpur and Muzaffarnagar and minimum at Dehradun respectively.

Average concentration values of sodium adsorption ratio in different river water and associated soil sediment samples (Table-XVI, Fig. 34) are given as follows.

YR.W. (0.71), YR.S (0.93)
HR.W. (0.69), HR.S. (0.75)
KR.W. (0.69), KR.S. (0.78)
GR.W. (0.76), GR.S. (0.94)

DISCUSSION :

The area under study lies in upper Ganga-Yamuna doab is heavily industrialized and agriculturally productive. Numerous industries,

increasing consumption of various fertilizers and pesticides, soil amendments, alkali and saline soils and source rocks are the prime sources of cations in the study area. Substantial amount of these may eventually leached down to groundwater, thereby increasing its salinity. Semi-arid climate, poor drainage and water logging conditions also increase alkalinity and salinity of water and soils.

Yamuna river water and soil samples have higher average concentration of calcium (175.0 ppm) and Mg (19.50 ppm) and minimum of potassium (5.7 ppm) respectively. On the whole, average concentration of cations in water and soil samples of Yamuna river generally follow the sequence given below.

YR.W. - Ca > Mg > Na > K

YR.S. - Mg > Na > Ca > K

Hindon river water and soil samples have maximum concentration of calcium (299.4 ppm) and Na (16.03 ppm) and minimum of potassium (4.12 ppm) respectively. Total average concentration of cations in water and soil sediment samples is as follows.

HR.W. - Ca > Na > Mg > K

HR.S. - Na > Mg > Ca > K

Kali-nadi water and associated soil samples have higher concentration of Ca (275.4 ppm) and Na (19.2 ppm) and minimum of potassium (5.8 ppm) as compared to other elements respectively. General sequence of average concentration of cations is given below.

KR.W. - Ca > Mg > Na > K
KR.S. - Na > Mg > Ca > K

Ganga river water and associated soil samples have higher average concentration of Ca (246.5 ppm) and Na (19.5 ppm) and minimum of potassium (6.5 ppm) as compared to other cations respectively. Total average concentration of Ca, Mg, Na and K in water and soil samples is noticed in the following order.

GR.W. - Ca > Mg > Na > K
GR.S. - Na > Ca > Mg > K

Groundwater samples have higher average concentration of Ca (167.7 ppm) and minimum of potassium (7.0 ppm), whereas associated soil samples have higher concentration of Na (17.26 ppm) and minimum of K (5.2 ppm) as compared to other cations. Sequence of abundance of cations is given as follows.

G.W. - Ca > Na > Mg > K
G.S. - Na > Mg > Ca > K

Triangular diagram (Fig. 35) reveals the comparison of cations in river waters. Most of the samples lie towards Ca-Mg side and follow the sequence Ca> Mg> Na almost in all river water samples. Figure-36 reveals variation of cations in Ca-Mg-Na triangular diagram in all soil samples of Yamuna, Hindon, Kali, and Ganga rivers. Most of the samples fall towards Na-Mg side and follow the sequence Na> Mg> Ca in percentages.

Average concentration ranges of Ca, Mg, Na and K are well below the recommended limits as prescribed by ISI, ICMR, WHO and USGS Water Supply for potable and irrigation waters and soils (Ca 200 ppm, Mg 150 ppm, Na 200 ppm and K 10 ppm) but concentration of calcium exceeds much above the permissible limits in river and groundwaters of Meerut, Ghaziabad and Saharanpur districts. Anomalously high values of Ca (503.5 ppm) owe their origin to the unscientific use of Ca-fertilizers and Ca-rich soil covers in the area which leach down to the saturated zone, thereby increasing the concentration of Ca to groundwater.

Table-I : Principal Chemical Constituents in Groundwater - Their Sources, Concentrations and Effect on Usability. (USGS Water Supply Paper, 1812, 1964).

Constituents	Major Natural sources	Concentration in Natural water	Effect on Usability of water
Calcium	Amphiboles, feldspars, gypsum, pyroxenes, calcite, aragonite, dolomite, clay minerals	Generally less than 100 mg/l; brines may contain 75000 mg/l. W.H.O. International (200 mg/l)	Calcium and magnesium combine with bicarbonate, carbonate, sulphate and silica to form heat-retarding, pipe-clogging scale in boilers and in other heat-exchange equipment. Ca and Mg combine with ions of fatty acids in soaps to form soap suds; the more Ca and Mg, the more soap required to form suds. A high concentration of Mg has a laxative effect, especially on new users of supply.
Magnesium	Amphiboles, olivines, pyroxenes, dolomite, magnesite, clay minerals	Generally less than 50 mg/l; ocean water contains more than 1000 mg/l, and brines may contain as mcuh as 57000 mg/l W.H.O.European - 125 mg/l. W.H.O.International - 150 mg/l	
Sodium	Feldspars (albite) clay minerals, evaporites, such as halite and mirabilite; industrial wastes	Generally less than 200 mg/l; about 10000 mg/l in sea-water; about 25000 mg/l in brines	More than 50 mg/l Na and K in presence of suspended matter causes foaming, which accelerates scale formation and corrosion in boilers. Na and K carbonate in recirculating cooling water can cause deterioration of wood in cooling towers. More than 65 mg/l of sodium can cause problems in ice manufacturing.
Potassium	Feldspars (orthoclase and microcline), feldspathoids, some micas, clay minerals	Generally less than 10 mg/l; as much as 100 mg/l in hot springs; as much as 25000 mg/l in brines	

CHAPTER VIII

HEAVY METAL POLLUTION

CHAPTER-VIII

HEAVY METAL POLLUTION

The results of chemical analyses of various heavy metals, their concentration range, average content, occurrence and correlation have been discussed in river and groundwaters and associated soil sediments in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr in western Uttar Pradesh. The contents of various heavy metals, Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr and Cd in Yamuna, Hindon, Kali and Ganga river waters, groundwaters and associated soil sediment samples at different sampling stations have been presented in Tables-II and III.

The prime objectives of the present study are to find out various source and causes and extent of heavy metal pollution in water bodies and associated soil sediments in order to suggest measures to prevent or eliminate the pollutional hazards and to make the better use of these water bodies for animal, human and agricultural purposes in the study region in the near future. The study also aims to investigate the impact of urban run-off, municipal, radioactive (Narora, Atomic Power Station in Bulandshahr district), industrial and agricultural waste

effluents on the concentration of Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr and Cd metals in water, soil sediments and plants of Yamuna, Hindon, Kali and Ganga rivers. An attempt has also been made to discuss the mechanism of sedimentation of metals through pH, organic matter and calcium carbonate solution because the chemistry of rocks, soils, plants and water in a particular ecosystem may be causally related, either directly or indirectly to the occurrence of animal and human diseases and growth of plants.

YAMUNA RIVER POLLUTION :

Introduction :

Yamuna originates from Yamunotri glacier, ten kms, west of the famous Himalayan peak Badar Punch. It then comes to Dehradun and afterwards to Delhi and western Uttar Pradesh passing through the districts of Saharanpur, Muzaffarnagar, Meerut, Ghaziabad, Bulandshahr along north-western border of Uttar Pradesh and finally meets the river Ganges at Allahabad, situated at the south-central tip of the state. Along its way it passes through some very important cities that are very thickly populated and highly industrialized. Due to the unplanned industrialization and population explosion of the country the rivers have become

one of the most heavily polluted water courses in the country. The Yamuna river while passing through the capital city of Delhi, receives large amount of its domestic and industrial effluents. To an approximate estimate about 200 million gallons of wastewater is released daily into the river from Delhi. The quantity of untreated wastewater getting into Yamuna river is put at about 5,15000 kilo-litres/day. In most of the developed countries the disposal of the sewage and industrial waste is often conducted without critical appraisal of the impact upon receiving waters. There are numerous sources of the domestic and industrial effluents leaching to heavy metal enrichment in water, sediments, vegetation and various fauna including fishes.

Survey of heavy metal concentrations in Yamuna river basin has been conducted by Deshpande, et al. (1972); Murthy, et al. (1978); Chandra, et al. (1979); Sanzigiri, et al. (1979); Israili (1980); Khandelwal, et al. (1980); Handa, et al. (1983); Sharma and Pathak (1984); Verma and Sharma (1984); Khurshid (1984); and Khurshid and Khan (1984) and reported high content of Fe (6.0 ppm), Zn (9.0 ppm), Cd (0.25 ppm), Cu (3.8 ppm) and Ni (16.5 ppm) in water and soil sediments.

Chemical Constituents :

Iron :

In the district Saharanpur, the Fe content in river water and associated soil sediment samples ranges from 1.40 to 3.1 ppm respectively. At Muzaffarnagar, Meerut and Bulandshahr, Fe content varies from 3.95 to 6.45; 0.73 to 4.84; 2.73 to 10.39 ppm and 1.01 to 2.08; 1.01 to 11.01; 6.29 to 11.01 ppm in river waters and associated soil sediment respectively. Maximum concentration is reported at Delhi Yamuna bridge, which varies from 3.55 to 10.47 ppm and 7.01 to 12.01 ppm in river waters and associated soil sediments respectively. Figures 37 and 38, figures 45 and 46 reveal the variation of Fe concentration in waters and associated soil sediment samples.

Average concentration of Fe (Figs. 53 and 57) in river water (Table-VI) and associated soil sediments (Table-VIII) along both sides of river is as follows.

Side-A : *R.W. (2.78), **R.S. (6.6)

Side-B : R.W. (4.30), R.S. (3.6)

---

*R.W. = River Water

**R.S. = River Soil

Total average concentration of Fe (Fig. 61) in river water and associated soil sediments is 3.54 and 5.1 ppm respectively (Tables-VII and IX). The Fe content of soil sediment samples is found significantly higher than those of river water samples.

Copper :

In the Saharanpur district, the copper content in river water and associated soil sediments varies from 0.13 to 0.17 ppm and 0.07 to 1.24 ppm respectively. Concentration range at Muzaffarnagar, Meerut, Delhi Yamuna bridge and Bulandshahr districts in Yamuna river water and associated soil sediments varies from 0.2 to 0.23; 0.06 to 0.15; 0.36 to 0.59; 0.11 to 0.21 ppm and 0.07 to 0.9; 0.34 to 1.27; 4.62 to 5.56 and 0.39 to 3.57 ppm respectively (Figs. 37, 38, 45 and 46). Maximum concentration of copper is noticed at Delhi Yamuna brdige in water and soil samples.

Average concentration of Cu (Figs. 53,and 57) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (0.15), R.S. (1.33)
Side-B : R.W. (0.19), R.S. (1.24)

Total average concentration of Cu (Fig. 61) in river water and associated soil sediments is 0.17 and 1.28 ppm respectively

(Tables-VII and IX). Average concentration of Cu in soil sediment samples is higher than associated water bodies.

Zinc :

Zinc is one of the most abundant heavy metals of sea water. Zinc concentration in the river water and associated soil sediment samples of Saharanpur and Muzaffarnagar districts varies from 3.87 to 4.33; 3.99 to 4.43 ppm and 0.29 to 0.45; and 0.54 to 0.69 ppm respectively. River water samples which have been collected at Meerut, Delhi and Bulandshahr, show highest concentration of Zinc (6.38, 7.18 and 5.67 ppm respectively) among all the samples, whereas associated soil sediment samples show lower concentration of zinc (3.93, 1.91, 1.25 ppm respectively). Maximum concentration of zinc in soil sediment is found at Meerut (3.93 ppm). Figures-37, 38, 45 and 46 show variation of zinc content in river waters and associated soil sediments.

Average concentration of Zn (Figs. 53 and 57) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (3.5), R.S. (0.85)

Side-B : R.W. (4.44), R.S. (1.13)

Total average concentration of zinc (Fig. 61) in water and associated soil sediment samples is 3.97 and 0.99 ppm respectively (Tables-VII and IX). Average concentration of zinc in river water samples is higher than associated soil sediment samples.

Nickel :

The concentration range of Ni in river water and soil sediment samples at Saharanpur and Muzaffarnagar is found in the range of 1.7 to 2.3; 1.29 to 1.70 ppm; and 9.62 to 12.03; 9.64 to 10.43 ppm respectively, whereas in Meerut district it is 0.29 to 2.68 ppm and 6.8 to 12.76 ppm respectively. Maximum concentration is found at Delhi (11.71 to 12.72) and Bulandshahr (9.02 to 12.61) in soil sediments and in river water samples it is 2.8 ppm and 2.18 ppm respectively. Variation of Ni content in river water and associated soil sediment samples is shown in figures 37, 38, 45 and 46.

Average concentration of nickel (Figs. 53 and 57) in river (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (1.5), R.S. (11.5)

Side-B : R.W. (1.69), R.S. (10.9)

Total average concentration of Ni (Fig. 62) in river water and associated soil sediment samples is 1.59 and 11.2 ppm respectively (Tables-VII and IX). Average concentration of nickel in soil sediment is higher than associated river water samples.

Cobalt :

Concentration range at Muzaffarnagar, Meerut, Delhi and Bulandshahr districts in Yamuna river water and associated soil sediment samples is 0.28, 0.27, 0.32, 0.29 ppm and 0.54, 0.39, 0.29, 0.51 ppm respectively. Maximum concentration of cobalt is found at Delhi Yamuna bridge (0.32 ppm) and minimum at Saharanpur in river water.

Average concentration of cobalt (Figs. 53 and 57) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (0.19), (0.38)
Side-B : R.W. (0.08), (0.29)

Total average concentration of cobalt (Fig. 62) in river water and associated soil sediment samples is 0.13 and 0.33 ppm respectively (Tables-VII and IX).

Lead :

Kopp, et al. (1967) has investigated that natural waters may contain lead up to 0.8 mg/l. Lead chromate paints in steel storage and old pipe installations may permit lead to be absorbed, particularly by soft acid waters.

The concentration of lead in river water and associated soil sediment samples of district Saharanpur is found in the range of 0.03 to 0.11 ppm and 0.0 to 2.91 ppm respectively, whereas in district Muzaffarnagar it ranges in between 0.02 to 0.09 ppm and 0.71 to 2.25 ppm respectively. River water samples at Meerut, Delhi and Bulandshahr districts have the concentration range from 0.16 to 0.20; 0.07 to 0.08 and 0.04 to 0.16 ppm respectively, whereas associated soil sediment samples contain 0.27 to 2.02; 0.12 to 0.53 and 0.03 to 1.69 ppm. Variation of lead content in river water and soil sediment has been shown in figures 37, 38, 45 and 46.

Average concentration of Pb (Figs. 53 and 57) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river bank is as follows.

Side-A : R.W. (0.11), R.S. (1.6)

Side-B : R.W. (0.11), R.S. (0.71)

Total average concentration of Pb (Fig. 62) in river water and associated soil sediment samples is 0.11 and 1.15 ppm respectively. River water samples have lower concentration than associated soil sediment samples (Tables-VII and IX).

Manganese :

Manganese in surface water is transported both in the solution form as well as adsorbed onto suspended clayey and organic matter. Some manganese may be released to the atmosphere by natural sources, viz., sea salt spray, industrial activities (iron and steel furnaces, mining of manganese ore), etc. The Environmental Studies Board (1973) has recommended unit of 20 microgram/l of Mn in marine aquatic environment.

Concentration of manganese in river water at Saharanpur, Muzaffarnagar, Meerut, Delhi and Bulandshahr is found in the range of 0.04 to 5.16; 1.49 to 5.59; 3.3 to 5.37; 6.69 to 7.8 and 0.33 to 5.24 ppm respectively, whereas in associated soil sediment it varies from 0.08 to 6.79; 1.8 to 6.53; 5.06 to 5.2; 5.07 to 5.18 and 4.97 to 5.49 ppm respectively. Maximum concentration in river water is found at Delhi Yamuna brdige (7.8 ppm), whereas minimum at Saharanpur (0.04 ppm). Maximum concentration in associated soil sediment is noticed at Muzaffarnagar (6.53 ppm) and minimum at Saharanpur (0.08 ppm). Figures 37, 38, 45

and 46 show variation of Mn content in water and soil sediment samples in the area studied.

Average concentration of manganese (Figs. 53 and 57) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river bank is given as follows.

Side-A : R.W. (2.92), R.S. (4.39)
Side-B : R.W. (4.95), R.S. (5.63)

Total average concentration of manganese (Fig. 63) in river water and associated soil sediment samples is 3.9 and 5.01 ppm respectively. In general soil sediment samples have higher concentration of manganese than river water samples at the same place (Tables-VII and IX).

Chromium :

Chromium concentration in river water and associated soil sediment samples at Saharanpur, Muzaffarnagar, Meerut, Delhi and Bulandshahr ranges from 0.02 to 1.24; 0.18 to 0.8; 0.17 to 1.29; 0.12 to 0.4 and 0.0 to 1.06 ppm and 0.01 to 0.05; 0.02 to 0.06; 0.0 to 0.03; 0.0 to 0.02 and 0.02 to 0.04 ppm respectively. Chromium content is found to be higher in water samples than soil sediment samples at all the sampling stations.

Maximum (1.29 ppm) concentration of chromium in river water is noticed at Meerut, whereas minimum (0.02 ppm) at Delhi Yamuna bridge, and the maximum concentration (0.06 ppm) in soil is found at Muzaffarnagar whereas minimum (0.01 ppm) at Saharanpur.

Average concentration of chromium (Figs. 53 and 57) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river bank is as follows.

Side-A : R.W. (0.71), R.S. (0.03)
Side-B : R.W. (0.42), R.S. (0.02)

Average chromium (Fig. 63) content in water and soil samples is 0.56 and 0.02 ppm respectively. River water samples have higher average concentration of chromium than associated soil sediments (Tables-VII and IX).

Cadmium :

Cadmium content in river water and associated soil sediment samples at all the sampling stations ranges from 0.01 to 0.05 ppm and 0.01 to 0.07 ppm respectively. At most of the sampling sites cadmium concentration is below the detectable limit and at places show very low concentration, both in water and soil sediments. Majority of the river water and associated soil sediment samples do not show much variation in the cadmium concentration (Figs. 37, 38, 45 and 46).

Average concentration of cadmium (Figs. 53 and 57) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river bank is given as follows.

Side-A : R.W. (0.03), R.S. (0.003)
Side-B : R.W. (0.01), R.S. (0.01)

Total average concentration of cadmium (Fig. 63) in river water and soil sediment samples is 0.02 and 0.006 ppm respectively (Tables-VII and IX).

HINDON RIVER POLLUTION :

Introduction :

Hindon river is one of the worst polluted rivers in western Uttar Pradesh, passing through Doon valley and flows through the districts of Saharanpur, Muzaffarnagar, Meerut, Ghaziabad before finally meeting the Yamuna river in Bulandshahr district. A large number of industries, such as textile and paper mills (Star and Aggarwal Paper Mills in Saharanpur), alloy manufacturing industries, chemical industries, sugar factories, dairy and grain mill products, rubber and plastic industries, are located very close to Hindon river in western Uttar Pradesh. Hindon is in the vicinity of Star Paper Manufacturing Mill in the district

Saharanpur and the waste effluents from the mill are directly discharged into this river near village Tapri, where it turns dark brownish colour of the river water. Surface, groundwater and associated soil sediment samples have been collected at periodic sites using waste discharge point, as the origin. Water pollution studies conducted by Siddiqui (1981), pointed out an exceedingly high pollution load in the Hindon river waters.

Chemical Constituents :

Iron :

Concentration range of Fe in Hindon river water samples at Saharanpur (Star Paper Mill), Muzaffarnagar, Meerut and Ghaziabad city varies from 4.86 to 10.72; 2.27 to 3.73; 2.35 to 2.84 and 0.66 to 4.19 ppm respectively. Maximum concentration of Fe is found near Star Paper Mill (10.72 ppm) in Hindon river waters, whereas minimum at Ghaziabad (0.66 ppm). Soil sediment samples have almost similar concentration of Fe in the districts of Meerut and Ghaziabad (4.01 ppm). Concentration range of Fe in soil sediment samples at Muzaffarnagar and Saharanpur varies from 1.01 to 3.01 and 1.01 to 2.59 ppm respectively. There is no much variation of Fe content in soil sediments at different places. Figures 39, 40, 47 and 48 show the variation of Fe concentration in river waters and associated soil sediments.

Average concentration of Fe (Figs. 54 and 58) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is given as follows.

Side-A : R.W. (4.6), R.S. (2.63)
Side-B : R.W. (5.95), R.S. (1.99)

Total average concentration of Fe (Fig. 61) in river water and associated soil sediments is 5.29 and 2.33 ppm respectively (Tables-VII and IX). On an average water samples have higher concentration of Fe than the associated soil sediment samples.

Copper :

Concentration range of copper in water and associated soil sediment samples at Saharanpur (Star Paper Mill), Muzaffarnagar, Meerut and Ghaziabad city varies from 0.18 to 0.22; 0.15 to 0.36; 0.12 to 0.13 and 0.08 to 0.10 ppm, and 0.06 to 1.35; 0.30 to 0.55; 0.49 to 0.60 and 2.22 to 3.47 ppm respectively. Maximum concentration is occurred at Ghaziabad city in soil sediment (3.47 ppm) whereas minimum at Muzaffarnagar (0.30 ppm) and in water samples the maximum concentration was noticed at Muzaffarnagar and minimum at Ghaziabad city. Figures 39, 40, 47 and 48 show variation of copper in water and soil sediment samples.

Figures 54 and 58 show the average concentration of copper in river water (Table-VI) and associated soil sediments (Table-VIII) along both the sides of river which is given as follows.

Side-A : R.W. (0.18), R.S. (0.96)

Side-B : R.W. (0.16), R.S. (0.57)

Total average concentration of copper (Fig. 61) in river water and associated soil sediments is 0.17 and 0.76 ppm respectively (Tables-VII and IX).

Zinc :

Concentration range of zinc in river water and associated soil sediment samples at Saharanpur, Muzaffarnagar, Meerut, and Ghaziabad districts varies from 3.71 to 4.64; 4.17 to 4.50; 4.23 to 4.82 and 2.21 to 6.38 ppm, and 0.30 to 2.63; 0.44 to 2.12; 0.92 to 0.96 and 0.64 to 0.79 ppm respectively. Maximum (6.38 ppm) zinc content in river water is found at Ghaziabad city and in soil sediment at Saharanpur near Star Paper Mill (2.63 ppm). Figures 39, 40, 47 and 48 show variation of zinc in river water and associated soil sediment samples.

Average concentration (Figs. 54 and 58) of Zn in river water (Table-VI) and associated soil sediment (Table-VIII) along both sides of river is given as follows.

Side-A : R.W. (4.09), R.S. (1.12)

Side-B : R.W. (4.5), R.S. (0.91)

Total average concentration of Zn (Fig. 61) in river water and soil sediments is 4.29 and 1.81 ppm respectively (Tables-VII and IX). River water samples on an average have higher concentration than associated soil sediment samples.

Nickel :

Concentration of nickel in river water and soil sediment samples is 2.6, 2.3, 1.20 and 1.95 ppm, and 11.55, 12.18, 10.43 and 10.97 ppm at Saharanpur, Muzaffarnagar, Meerut and Ghaziabad districts respectively. Maximum (2.6 ppm) concentration of nickel in river water is revealed near Star Paper Mill at Saharanpur whereas minimum (0.2 ppm) at Muzaffarnagar. All soil sediment samples have much higher concentration of nickel as compared to water samples at various sampling stations. Maximum (12.18 ppm) concentration in soil sediment samples is found at Saharanpur and Muzaffarnagar districts. Figures 39, 40, 47 and 48 show variation of nickel in water and soil samples.

Average concentration of nickel (Figs. 54 and 58) in river water (Table-VI) and associated sediment (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (1.15), R.S. (10.8)

Side-B : R.W. (1.50), R.S. (9.76)

Total average concentration of nickel (Fig. 62) in river water and soil sediment is 1.32 and 10.28 ppm respectively (Tables-VII and IX).

Cobalt :

The concentration of cobalt in river water and soil sediment samples is found in the range of 0.08 to 0.43 ppm and 0.22 to 0.37 ppm respectively. The concentration of cobalt in water and soil sediment samples is 0.43 and 0.33 ppm respectively in the district of Saharanpur. Minimum concentration is occurred at Muzaffarnagar in water as well as in soil sediment samples. Maximum concentration (0.37 ppm) in soil samples is noticed at Meerut. The concentration of cobalt in river water and associated soil sediment samples is found in the range of 0.12 and 0.30 ppm respectively in Ghaziabad city. There is no much variation in the concentration range of cobalt in water and in soil sediment samples (Figs. 39, 40, 47 and 48).

Average concentration of cobalt (Figs. 54 and 58) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (0.09), R.S. (0.13)

Side-B : R.W. (0.05), R.S. (0.10)

Total average concentration of cobalt (Fig. 62) in water and associated soil sediment samples is 0.07 and 0.11 ppm respectively (Tables-VII and IX). Cobalt content in soil sediment is found to be higher than that of river water samples.

Lead :

Concentration range of lead in river water and associated soil sediment samples at Saharanpur, Muzaffarnagar, Meerut, and Ghaziabad districts varies from 0.05 to 0.13; 0.12 to 0.14; 0.0 to 0.15 and 0.09 to 0.10 ppm, and 0.0 to 1.40; 0.42 to 1.19; 0.97 to 1.04 and 0.81 to 0.88 ppm respectively. Maximum concentration in soil sediment samples is 1.40 ppm whereas in water it is 0.14 ppm. Soil sediment samples have higher concentration of lead than river water samples (Figs. 39, 40, 47 and 48).

Average concentration of lead (Figs. 54 and 58) in river water (Table-VI) and associated soil sediment (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (0.09), R.S. (0.78)

Side-B : R.W. (0.105), R.S. (0.59)

Total average concentration of lead (Fig. 62) in water and soil sediment samples is 0.09 and 0.68 ppm respectively (Tables-VII and IX).

Manganese :

Concentration of manganese in river water samples at Saharanpur, Muzaffarnagar, Meerut and Ghaziabad districts varies from 5.95 to 7.33; 5.99 to 6.30; 0.05 to 5.73 and 0.34 to 3.63 ppm respectively, whereas in soil sediment samples it varies from 0.44 to 6.38; 5.94 to 6.57; 5.0 to 5.10 and 0.26 to 5.16 ppm respectively. Among all the water and soil samples, manganese content has no much variation (Figs. 39, 40, 47 and 48).

Average concentration of manganese (Figs. 54 and 58) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (5.20), R.S. (5.01)
Side-B : R.W. (5.37), R.S. (5.11)

Total average concentration of manganese (Fig. 63) in water and associated soil sediment samples is 5.28 and 5.06 ppm respectively (Tables-VII and IX).

Chromium :

Maximum concentration of chromium in water and associated soil sediment samples at Saharanpur, Muzaffarnagar, Meerut and Ghaziabad districts is 0.35, 0.74, 0.93 and 0.32 ppm and 0.04, 0.02, 0.03 and 0.02 ppm respectively. Chromium content in river water is found to be higher than those of soil sediment samples. Minimum concentration of chromium in water and associated soil sediment samples is 0.14 and 0.01 ppm respectively. Figures 39, 40, 47 and 48 show variation of chromium in water and associated soil sediment samples.

Average chromium (Figs. 54 and 58) in river water (Table-VI) and soil sediment (Table-VIII) along both sides of the river is as follows.

Side-A : R.W. (0.37), R.S. (0.02)
Side-B : R.W. (0.26), R.S. (0.02)

Total average concentration of chromium (Fig. 63) in water and soil sediment samples is 0.31 and 0.02 ppm respectively (Tables-VII and IX).

Cadmium :

Maximum concentration of cadmium in water samples at Saharanpur, Muzaffarnagar, Meerut and Ghaziabad districts is 0.34, 0.39, 0.4, and 0.06 ppm respectively, whereas minimum (0.07 ppm) is found at almost all the sampling stations. Highest concentration of cadmium (0.38 ppm) in sediment is occurred at Muzaffarnagar, whereas the rest of the samples of soil have very low concentration (Figs. 39, 40, 47 and 48).

Average cadmium (Figs. 54 and 58) in river water (Table-VI) and soil sediment samples (Table-VIII) along both sides of river banks is as follows.

Side-A : R.W. (0.15), R.S. (0.004)
Side-B : R.W. (0.20), R.S. (0.05)

Total average concentration of cadmium (Fig. 63) in water and soil sediment samples is 0.17 and 0.02 ppm respectively (Tables-VII and IX).

KALI-NADI POLLUTION :

Introduction :

There are two tributaries which makes this river, one is Kali-nadi east and other Kali-nadi west. The Kali-west, rises from

Saharanpur, is the tributary of Hindon which joins it in south-east boundary of Pargana Burhana in district Muzaffarnagar. Kali-east river also known as the Nagin and also as the Kali-nadi east to distinguish it from Kali-west, a tributary of Hindon. The Kali or Kalindi rises in the north-east corner of Pargana Khatauli in district Muzaffarnagar and flowing almost south for a short distance in Muzaffarnagar district, it passes into Meerut, Bulandshahr and Aligarh districts. Generally it traverses undulating sandy slopes which are rarely cut up into rivines. It is joined in its course by three smaller streams, two of which are known by their generic name of Choiya.

Kali-nadi is also a much polluted river which receives most of its pollution load from various sources in the districts of Muzaffarnagar, Meerut and Bulandshahr in western Uttar Pradesh. High load of pollution in these districts is due to numerous sugar factories which are situated along and near the river. Large consumption of fertilizers for high yield of sugarcane crops in the area is also a major cause of river pollution.

Chemical Constituents :

Iron :

The Fe concentration in river water and associated soil samples of districts Saharanpur and Muzaffarnagar varies from 1.16 to

5.93, 0.82 to 10.17 ppm and 1.01 to 2.01 and 1.61 to 4.91 ppm respectively. River water and soil samples of districts Muzaffar-nagar and Bulandshahr have highest concentration of Fe, whereas samples of districts Saharanpur and Meerut have low concentration. The Fe content in river water and soil samples of districts Meerut and Bulandshahr city varies from 0.93 to 6.85 and 0.29 to 10.45 ppm, and 4.01 to 7.01 and 4.01 to 12.01 ppm respectively. Fe content in river soil is found to be higher than those of the river water (Figs. 41, 42, 49 and 50).

Average concentration of Fe (Figs. 55 and 59) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of the river is as follows.

Side-A : R.W. (4.6), R.S. (3.14)
Side-B : R.W. (2.9), R.S. (6.80)

Total average concentration of iron (Fig. 61) in water and associated soil sediment samples is 3.75 and 4.97 ppm respectively (Tables-VII and IX). Average concentration of Fe in soil sediment samples is higher than river water samples.

Copper :

The copper concentration in river water (Figs. 41 and 42) and associated soil sediment (Figs. 49 and 50) samples in Saharanpur,

Muzaffarnagar, Meerut and Bulandshahr districts varies from 0.13 to 0.16; 0.14 to 0.25; 0.09 to 0.14 and 0.03 to 0.16 ppm, and 0.20 to 0.43; 0.21 to 0.57; 0.79 to 5.47 and 3.25 to 9.73 ppm respectively. Concentration of copper in soil sediment samples is higher than the river water samples at all sampling station in Kali-nadi. Maximum concentration of copper is found at Bulandshahr city in soil sediments. On the whole, there is not much variation in the concentration range of copper in all water samples analysed in the study area.

Average concentration of copper (Figs. 55 and 59) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (0.13), R.S. (2.03)
Side-B : R.W. (0.12), R.S. (3.15)

Total concentration of copper (Fig. 16) in river water and associated soil samples is 0.12 and 2.59 ppm respectively (Tables-VII and IX). On the average, concentration of copper is higher in soil samples than associated river water samples.

Zinc :

The zinc concentration in river water (Figs. 41 and 42) and associated soil sediment (Figs. 49 and 50) samples of districts

Saharanpur, Muzaffarnagar, Meerut and Bulandshahr varies from 1.53 to 3.49; 4.02 to 4.55; 3.99 to 4.08 and 5.25 to 6.23 ppm, and 0.52 to 2.05; 0.39 to 0.97; 0.87 to 1.89 and 0.52 to 2.03 ppm respectively. Zinc concentration in river water samples is higher than associated soil sediment samples at all sampling sites, but not much variation is noticed in the river water samples. Maximum concentration of zinc is noticed at Bulandshahr in both river water and soil samples.

Average concentration of zinc (Figs. 55 and 59) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (3.9), R.S. (1.00)
Side-B : R.W. (4.65), R.S. (1.02)

Total average concentration of zinc (Fig. 61) in river water and associated soil sediment samples is 4.27 and 1.01 ppm respectively. Zinc content in river water is higher than associated soil sediment samples.

Nickel :

The nickel concentration in river water (Figs. 41 and 42) and associated soil sediment (Figs. 49 and 50) samples of districts Saharanpur, Muzaffarnagar, Meerut and Bulandshahr varies from

2.8 to 3.7; 1.7 to 4.2; 1.55 to 2.85 and 0.38 to 1.48 ppm and 9.7 to 10.83; 10.5 to 13.07; 7.89 to 11.85 and 9.18 to 13.83 ppm respectively. Maximum concentration of nickel is found in soil sediment samples of districts Muzaffarnagar (13.07 ppm) and Bulandshahr (13.83 ppm) whereas maximum concentration (4.2 ppm) in river water samples is noticed in Muzaffarnagar district and minimum (0.38 ppm) in Bulandshahr district.

Average concentration of nickel (Figs. 55 and 59) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river is as follows.

Side-A : R.W. (2.01), R.S. (11.42)
Side-B : R.W. (1.50), R.S. (10.72)

Total average concentration of nickel (Fig. 62) in river water (Table-VII) and associated soil sediment (Table-IX) sample is 1.7 and 11.07 ppm respectively. On an average, concentration of nickel is found to be higher in soil samples than river water samples.

Cobalt :

The concentration of cobalt in river water (Figs. 41 and 42) and associated soil sediment (Figs. 49 and 50) samples of districts Saharanpur, Muzaffarnagar, Meerut and Bulandshahr

varies from 0.03 to 0.12; 0.02 to 0.23; 0.23 to 0.33 and 0.09 to 0.31 ppm and 0.04 to 0.09; 0.01 to 0.16; 0.25 to 0.47 and 0.22 to 0.47 ppm respectively. There is no much variation in concentration of cobalt in both water as well as soil sediment samples. Maximum concentration (0.33 ppm) of cobalt in water samples is occurred at Meerut and minimum at Muzaffarnagar (0.02 ppm), whereas soil samples have maximum concentration (0.47 ppm) of cobalt at Meerut and Bulandshahr and minimum (0.01 ppm) at Muzaffarnagar.

Average concentration of cobalt (Figs. 55 and 59) in river water (Table-VI) and associated soil sediment (Table-VIII) samples along both sides of river is mentioned as follows.

Side-A : R.W. (0.14), R.S. (0.20)
Side-B : R.W. (0.15), R.S. (0.20)

Total average concentration of cobalt (Fig. 62) in river water (Table-VII) and associated soil sediment (Table-IX) samples is 0.14 and 0.20 ppm respectively. There is not much variation in the concentration range of cobalt in water and soil sediment samples in this river basin.

Lead :

The lead concentration in river water (Figs. 41 and 42) and associated soil sediment (Figs. 49 and 50) samples of the districts Saharanpur, Muzaffarnagar, Meerut and Bulandshahr varies from 0.07 to 0.09; 0.10 to 0.12; 0.01 to 0.21 and 0.05 to 0.11 ppm and 0.06 to 0.28; 0.27 to 0.43; 1.23 to 2.79 and 0.47 to 1.3 ppm respectively. Maximum concentration of lead in water and soil sediment samples is 0.21 and 2.79 ppm respectively which was revealed from the samples collected in Meerut. On the whole, soil samples have higher concentration of lead than water samples at all the sampling stations.

Average concentration of lead (Figs. 55 and 59) in river water (Table-VI) and associated soil samples (Table-VIII) along both sides of river is given below.

Side-A : R.W. (0.09), R.S. (0.69)

Side-B : R.W. (0.08), R.S. (0.72)

Total average concentration of lead (Fig. 62) in river water (Table-VII) and associated soil sediment (Table-IX) samples is 0.08 and 0.70 ppm respectively. Average concentration of lead in soil sediment is found to be higher than water.

Manganese :

Concentration of manganese in river water and associated soil sediment samples of district Saharanpur varies from 5.08 to 6.52 ppm and 5.79 to 6.22 ppm respectively, whereas in district Muzaffarnagar it varies from 3.61 to 5.86 ppm and 0.21 to 6.63 ppm respectively. There is not much difference in the concentration range of manganese in both the water (0.24 to 7.65 ppm) and soil sediment (0.23 to 5.45 ppm) samples at different places in the districts of Meerut and Bulandshahr (Figs. 41 and 42 and Figs. 49 and 50).

Average concentration of manganese (Figs. 55 and 59) in river water (Table-VI) and associated soil sediment (Table-VIII) samples along both banks of river is given below.

Side-A : R.W. (3.4), R.S. (4.14)
Side-B : R.W. (3.89), R.S. (5.63)

Total average concentration of manganese (Fig. 63) in river water (Table-VII) and associated soil sediment (Table-IX) samples is 3.6 and 4.8 ppm respectively.

Chromium :

The chromium concentration in river water (Figs. 41 and 42) samples in Saharanpur, Muzaffarnagar, Meerut, and Bulandshahr districts varies from 0.11 to 0.31; 0.01 to 0.23; 0.36 to 1.08 and 0.17 to 0.96 ppm respectively, whereas in soil samples it ranges between 0.02 to 0.04 ppm. Soil samples (Figs. 49 and 50) have much lower concentration range than the water samples.

Average concentration of chromium (Figs. 55 and 59) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both the banks of the river is listed as follows.

Side-A : R.W. (0.23), R.S. (0.02)
Side-B : R.W. (0.40), R.S. (0.02)

Total average concentration of chromium (Fig. 63) in river water (Table-VII) and associated soil sediment (Table-IX) samples is 0.30 and 0.02 ppm respectively. Average concentration of chromium in water samples is much higher than those of soil sediment samples in this river catchment.

Cadmium :

Concentration of cadmium in river water (Figs. 41 and 42) samples of districts Muzaffarnagar and Bulandshahr varies

from 0.02 to 0.06 and 0.01 to 0.07 ppm and at many sampling stations it is below the detectable limits (Figs. 49 and 50). Maximum (0.01 ppm) concentration of cadmium in soil sediment samples is reported at Bulandshahr city, whereas rest of the soil samples have quite low concentration. River water samples have slighly higher concentration of cadmium than those of soil sediment samples.

Average concentration of cadmium (Figs. 55 and 59) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both the sides of river is given below.

Side-A : R.W. (0.03), R.S. (0.001)
Side-B : R.W. (0.01), R.S. (0.000)

Total average concentration of cadmium (Fig. 63) in water (Table-VII) and associated soil sediment (Table-IX) samples is 0.02 and 0.0005 ppm respectively. Soil sediment samples on the whole, have much lower concentration of cadmium than those of water samples.

GANGA RIVER POLLUTION :

Introduction :

The Ganges river originates in mighty Himalayan mountain in an ice cave known as 'Gow Mukh' at the height of about 6614 m

in Tehri Garhwal of U.P., out of the ice-cave it pours out onto the land and flows on and across Uttar Pradesh, Bihar, Bengal where finally it merges into Bay of Bengal. During the course of its journey, covering about 2523 km, it passes through several important cities (Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr in western Uttar Pradesh) which are thickly populated and highly industrialized. While passing through those cities of Ganga-Yamuna doab, Ganga river receives large volume of domestic and industrial effluents from them. The disposal of the two types of the waste waters has posed a perennial problem and resulted in gross pollution of the river, due to which the Ganga river has become one of the most heavily polluted rivers in India. The worst culprits for the degradation of water quality of river are the community sewage, ashes of the burnt bodies and unburnt dead bodies cremated near its banks and industrial effluents containing various pollutants.

In recent years, due to the awareness about pollution, Government and scientists in almost all countries have sought to initiate programmes for the monitoring and abatement of river pollution including the heavy metal pollution in various rivers.

The survey of heavy metals has been conducted by Oliver (1973); Adams, et al. (1973); Kim (1974); Muller and Forstner (1975); Mutlak, et al. (1980); Muller (1980); Forstner and Wittmann (1981) in various river waters and associated soil sediments.

The survey of heavy metal contents in Ganga river water and sediments has been investigated by Bhargava (1977); Sharma (1980); Gupta and Pande (1980); Khapalia, et al. (1981); Ajmal, et al. (1982); Das Gupta (1982-83); Handa (1983); Handa, et al. (1984); Ghosh, et al. (1984); Gupta, et al. (1984); Bilgrami and Munshi (1984); and Mehrotra, et al. (1984) and reported maximum concentration of Fe (5.5 ppm), Cr (21.00 ppm), Cu (15.00 ppm), Mn (10.0 ppm) and Zn (9.0 ppm).

Chemical Constituents :

Iron :

Iron concentration in river water at Rishikesh, Raibala and Hardwar in Dehradun district is 5.74, 4.47, and 5.08 ppm respectively whereas in soil sediments it is 2.01, 2.47 and 2.01 ppm respectively. The iron concentration in river water (Figs. 43 and 44) and associated soil sediment (Figs. 51 and 52) samples of Dehradun district varies from 2.64 to 7.21 ppm and 2.01 to 2.47 ppm respectively. Maximum (7.21 ppm) concentration of iron in Ganga river water is found at Hardwar and minimum (2.62 ppm) at Rishikesh. Maximum (2.47 ppm) concentration in soil samples is found at Raibala and rest of the samples have 2.01 ppm of iron on the average. Maximum concentration of iron in river water and associated soil sediments samples of Saharanpur and Muzaffarnagar is noticed as 10.33 and 3.11 ppm

and 2.01 and 3.01 ppm respectively. The Fe content in river water and associated soil sediment samples of district Meerut and Bulandshahr (Narora) varies from 3.94 to 10.69 and 7.17 to 11.9 ppm and 2.01 to 4.63 and 6.01 to 10.82 ppm respectively. Maximum concentration of Fe in water and soil samples is occurred at Narora (Bulandshahr). There is not much variation in the concentration range of Fe in water and associated soil samples in the basin.

Average concentration of iron (Figs. 56 and 60) in river water (Table-VI) and associated soil sediment (Table-VIII) samples along both banks of river is listed as follows.

Side-A : R.W. (6.3), R.S. (3.79)
Side-B : R.W. (7.46), R.S. (3.75)

Total average concentration of Fe (Fig. 61) in river water (Table-VII) and associated soil sediment (Table-IX) samples is 6.88 and 3.77 ppm respectively. The iron content of river water samples is found significantly higher than those of associated soil sediment samples.

Copper :

The copper concentration in river water (Figs. 43 and 44) samples at Dehradun, Saharanpur, Muzaffarnagar, Meerut and

Bulandshahr varies from 0.12 to 0.25; 0.14 to 0.23; 0.12 to 0.15; 0.07 to 0.42 and 0.04 to 0.15 ppm respectively, whereas in soil sediment (Figs. 51 and 52) samples it varies from 0.37 to 5.85; 0.32 to 1.64; 0.38 to 0.42; 0.37 to 0.82 and 3.43 to 11.79 ppm respectively. There is only a slight variation in the concentration range of copper content in all river water samples collected whereas soil sediment samples reveal significant variations. Copper content of river water samples is found significantly lower than those of the soil sediment samples. Maximum content of Cu in water (0.42 ppm) and soil (11.79 ppm) samples is obtained at Meerut and Bulandshahr districts respectively.

Average concentration of copper (Figs. 56 and 60) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both banks of the river is found to be as follows.

Side-A : R.W. (0.11), R.S. (2.73)
Side-B : R.W. (0.17), R.S. (3.8)

There is not much variation in the concentration of side-A and B of water and soil sediment samples. Total average concentration of copper (Fig. 61) in river water (Table-VII) and associated soil sediment (Table-IX) samples is 0.14 and 3.26 ppm respectively. Soil sediment samples on the whole have significantly higher concentration of Cu than those of water samples.

Zinc :

The concentration of zinc in river water (Figs. 43 and 44) and associated soil sediment (Figs. 51 and 52) samples of districts Dehradun, Saharanpur, Muzaffarnagar, Meerut and Bulandshahr varies from 3.53 to 4.38; 3.96 to 4.31; 4.27 to 4.34; 4.3 to 6.3 and 5.0 to 6.36 ppm and 0.48 to 1.27; 0.24 to 0.45; 1.54 to 11.72; 0.74 to 1.46 and 0.44 to 0.089 ppm respectively. Maximum concentration (6.36 ppm) of zinc in river water is obtained at Bulandshahr (Narora) and minimum (3.53 ppm) at Dehradun (Hardwar). Maximum concentration (11.72 ppm) of zinc in soil sediment samples is obtained at Muzaffarnagar, and minimum (0.24 ppm) at Saharanpur. There is not much variation of zinc concentration in river water samples, whereas soil samples reveal a significant variation.

Average concentration of zinc (Figs. 56 and 60) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along river banks is as follows.

Side-A : R.W. (4.9), R.S. (0.85)
Side-B : R.W. (4.6), R.S. (1.90)

River water samples of side-A have higher concentration than the water samples of side-B, whereas soil sediment samples of

side-B have higher concentration than samples of side-A. River water samples on the average have high concentration of zinc than the soil samples.

Total average concentration of zinc (Fig. 61) in river water (Table-VII) and associated soil samples (Table-IX) is 4.7 and 1.37 ppm respectively.

Nickel :

Nickel concentration in river water (Figs. 43 and 44) and associated soil sediment (Figs. 51 and 52) samples in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut and Bulandshahr varies from 0.86 to 1.64; 0.26 to 1.15; 0.0 to 3.50; 1.05 to 2.9 and 0.34 to 2.02 ppm and 9.93 to 14.35; 9.77 to 9.95; 10.52 to 12.17; 9.83 to 11.53 and 9.06 to 12.27 ppm respectively. Maximum concentration (3.50 ppm) of nickel in river water samples is determined at Muzaffarnagar, whereas minimum concentration (0.26 ppm) is obtained at Saharanpur. Maximum concentration (14.35 ppm) of nickel in soil sediment samples is obtained at Dehradun (Hardwar), whereas minimum concentration (9.06 ppm) is noticed at Bulandshahr (Anupshahr). Nickel content of soil sediment samples is found significantly much higher than those of river water samples of the same place.

Average concentration of nickel (Figs. 56 and 60) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river bank is given below.

Side-A : R.W. (1.5), R.S. (10.00)
Side-B : R.W. (1.16), R.S. (11.7)

Concentration of Ni in side-A and side-B samples is approximately same in water as well as in soil sediment samples. Soil sediment samples of both sides have much higher nickel content than those of water samples.

Total average concentration of nickel (Fig. 62) in river water (Table-VII) and associated soil sediment (Table-IX) samples is 1.33 and 10.85 ppm respectively.

Cobalt :

Cobalt concentration in river water (Figs. 43 and 44) and associated soil sediment (Figs. 51 and 52) samples in the districts of Dehradun, Saharanpur, Meerut and Bulandshahr varies from 0.17 to 0.41; 0.22 to 0.48; 0.03 to 0.28 and 0.03 to 0.33 ppm and 0.37 to 0.43; 0.37 to 1.06; 0.09 to 0.28 and 0.11 to 0.34 ppm respectively. Minimum concentration of cobalt in both water (0.02 ppm) and soil sediment (0.04 ppm) is obtained at Muzaffarnagar whereas maximum concentration (0.48 ppm) in river water samples is obtained at Saharanpur.

Average concentration of cobalt (Figs. 56 and 60) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both sides of river bank is as follows.

Side-A : R.W. (0.16), R.S. (0.33)
Side-B : R.W. (0.25), R.S. (0.25)

Total average concentration of cobalt (Fig. 62) in river water (Table-VII) and associated soil sediment samples (Table-IX) is 0.20 and 0.29 ppm respectively. Soil sediment samples have slightly higher concentration than those of water samples.

Lead :

Lead concentration in river water (Figs. 43 and 44) and associated soil sediment samples (Figs. 51 and 52) in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut and Bulandshahr varies from 0.01 to 0.36; 0.08 to 0.09; 0.0 to 0.15; 0.14 to 0.17 and 0.01 to 0.05 ppm and 0.81 to 3.09; 0.81 to 0.95; 0.43 to 1.12; 0.28 to 2.27 and 0.54 to 0.84 ppm respectively. Dehradun (Raibala) contain maximum (0.36 ppm) and (3.09 ppm) of lead in both river water and soil samples resepctively, whereas minimum concentration (0.01 ppm) and (0.28 ppm) in water and soil samples is noticed in Bulandshahr (Ramghat) and Meerut respectively. On an average soil sediment samples have much higher concentration of lead than the associated river water samples.

Figures 56 and 60 reveal the average concentration of lead in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both the sides of river bank which is given below.

Side-A : R.W. (0.09), R.S. (0.92)
Side-B : R.W. (0.107), R.S. (0.97)

Total average concentration of lead (Fig. 62) in river water (Table-VII) and soil sediment samples (Table-IX) is 0.09 and 0.94 ppm respectively.

Manganese :

Concentration of manganese in river water (Figs. 43 and 44) and associated soil sediment (Figs. 51 and 52) in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut and Bulandshahr varies from 0.01 to 0.47; 0.01 to 0.43; 3.96 to 5.36; 0.71 to 5.86 and 0.17 to 5.9 ppm and 0.26 to 5.70; 4.29 to 5.17; 6.31 to 6.72; 0.35 to 6.47 and 5.06 to 5.42 ppm respectively. Maximum concentration of Mn (5.9 ppm) in water is obtained at Bulandshahr and Meerut and minimum (0.01 ppm) is occurred at Hardwar. Maximum (6.72 ppm) and minimum concentration (0.26 ppm) of manganese in soil samples is obtained at Muzaffarnagar and Hardwar respectively.

Average concentration of manganese (Figs. 56 and 60) in river water (Table-VI) and associated soil sediment (Table-VIII) samples along both the sides of river is given below.

Side-A : R.W. (3.2), R.S. (4.86)
Side-B : R.W. (1.10), R.S. (4.7)

Soil samples of both sides have significantly higher average concentration than those of water samples. Total average concentration of manganese (Fig. 63) in river water (Table-VII) and soil sediment (Table-IX) samples is 2.15 ppm and 4.78 ppm respectively.

Chromium :

Naturally occurring chromium is cheifly in the form of chromite. Because of increasing use of chromium (VI) in industries as in alloy preparation, plating, tanning, corrosion inhibition, wood preservation, chromium finds way in natural bodies of water. There are several electroplating factories in area which discharge waste to the sewers without treatment. Other chemicals employed in the process of electroplating like hydrochloric acid, nitric acid, chromic acid, salts of zinc, cadmium, nickel and copper and caustic soda also come along with chromium (III). Chromium (VI), in the form of chromate or dichromate, is, however, much more mobile and has ability to penetrate cell

membranes to much higher degree than Cr (III) and as such is much more toxic.

The anthropogenic sources contribute chromium to the environment in three different ways.

1. Emission of waste gases or aerosol particles containing chromium e.g. during burning of coal, oil, cement manufacturing, manufacture of refractories, etc.

2. Liquid waste effluents from various industries like metal plating, chromium chemicals manufacturing plants, dyeing, tanning, etc.

3. Disposal of solid waste on land, e.g. sewage sludge, solid waste from chromium chemicals manufacturing industries, etc.

Concentration of chromium in Ganga river water (Figs. 43 and 44) as well as in soil sediment (Figs. 51 and 52) samples varies from 0.16 to 0.99; 0.27 to 0.46; 0.31 to 0.58; 0.0 to 0.96 and 0.18 to 1.21 ppm and 0.03 to 0.05; 0.05 to 0.05; 0.03 to 0.04; 0.02 to 0.04 and 0.0 to 0.01 ppm respectively at Dehradun, Saharanpur, Muzaffarnagar, Meerut and Bulandshahr. Maximum (1.21 ppm) and minimum (0.16 ppm) concentration of chromium in river water samples are found at Bulandshahr (Narora) and Dehradun (Hardwar). The highest and lowest chromium concentration

in soil sediment samples are obtained in the localities of Dehradun and Saharanpur (0.05 ppm) and Bulandshahr (0.01 ppm) respectively. There is not much variation in the concentration range of chromium in soil sediment samples in the districts of Dehradun, Muzaffarnagar, Saharanpur and Meerut (0.02 to 0.05 ppm).

Average concentration of chromium (Fig. 56 and 60) in river water (Table-VI) and associated soil sediment (Table-VIII) samples along both sides of river is given as follows.

Side-A : R.W. (0.36), R.S. (0.02)
Side-B : R.W. (0.68), R.S. (0.03)

Total average concentration of chromium (Fig. 63) in river water (Table-VII) and soil sediment samples (Table-IX) is 0.52 ppm and 0.025 ppm respectively.

These data are in confirmity with the above observations which indicate much higher chromium concentration in river water samples than those of soil sediments samples in area.

Cadmium :

Cadmium concentration of river water samples (Figs. 43 and 44) is in the range of 0.01 to 0.02 (Dehradun); 0.0 to 0.19 (Saharanpur); 0.01 to 0.21 (Muzaffarnagar); 0.02 to 0.50

(Meerut) and 0.01 to 0.31 ppm (Bulandshahr). Maximum concentration of cadmium in river water samples is obtained at Meerut (0.50 ppm) and minimum at Dehradun and Muzaffarnagar districts. Similarly, maximum concentration (0.01 to 0.32 ppm) in soil sediment samples (Figs. 51 and 52) is found at Bulandshahr, whereas rest of the soil samples have undetectable concentration. The above data reflect that cadmium concentration in river water samples is significantly higher than the soil sediment samples.

Average concentration of cadmium (Figs. 56 and 60) in river water (Table-VI) and associated soil sediment samples (Table-VIII) along both the sides of the river is as follows.

Side-A : R.W. (0.009), R.S. (0.009)

Side-B : R.W. (0.13), R.S. (0.04)

Total average concentration of cadmium in the study area (Fig. 63) in river water (Table-VII) and soil sediment (Table-IX) samples is 0.07 and 0.02 ppm respectively. These data show that total average concentration of cadmium is higher in river water samples than those of soil samples at the same localities.

GROUNDWATER POLLUTION :

Introduction :

Groundwater pollution may be defined as artificially induced degradation of natural groundwater quality. Pollution can impair the use of water and can create hazards to public health through toxicity of metals. Principal sources and causes of groundwater pollution in the study area include municipal, industrial, agricultural, spills and surface discharges; stockpiles, septic tanks and cesspools, roadway deicing, saline water intrusion, interchange through wells, etc.

Heavy metals have been most frequently ranked as of serious potential hazard to aquatic ecosystem. High levels of heavy metals in a water body can be caused by atmospheric fall out, liquid effluents discharge and leaching of metal bearing minerals. It is more intensified with progress of industrialization and thus pollution become the price of industrial and urban development. The toxicity of waters varies with the interaction between their constituents and also due to physico-chemical factors such as temperature, DO, pH, alkalinity, hardness and dissolved minerals of the receiving waters.

Chemical Constituents :

The results of chemical analysis of various heavy metals (Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr and Cd), their concentration range and average content have been discussed in groundwater and associated soil sediment samples in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr in western Uttar Pradesh of Ganga-Yamuna doab. The results of chemical analyses of various heavy metals in groundwater as well as in associated soil sediment samples are presented in the Tables-II and III.

Iron :

The average content of iron in groundwater and associated soil sediment samples in the districts of Saharanpur, Muzaffarnagar, Meerut and Bulandshahr is found to be 2.35, 2.23, 0.85, 0.89 ppm and 2.01, 1.01, 2.01 and 2.01 ppm respectively.

Maximum concentration of iron in groundwater is obtained at Saharanpur (2.35 ppm), whereas minimum (0.89 ppm) at Bulandshahr. Maximum concentration (2.01 ppm) in soil sediment samples is found at Saharanpur and minimum (1.01 ppm) at Muzaffarnagar. Groundwater samples have slightly higher concentration than soil sediment samples at the same locality (Figs. 66 and 67).

Average concentration of iron in study area such as a whole (Fig. 68) in groundwater and soil sediment samples is 2.0 and 1.5 ppm respectively (Table-XVIII).

Copper :

Concentration range of copper in groundwater (Fig. 66) and associated soil sediment (Fig. 67) samples in the districts of Saharanpur, Muzaffarnagar, Meerut and Bulandshahr is 0.15, 0.14, 0.07 and 0.09 ppm and 17.59, 1.82, 0.17 and 2.86 ppm respectively. Maximum concentration of copper in both groundwater (0.15 ppm) and soil sediment samples (17.59 ppm) is reported in Saharanpur and minimum (0.07 ppm) and (0.17 ppm) in Meerut respectively. Groundwater samples have significantly lower concentration range of copper than soil sediment samples.

Average concentration of copper (Fig. 68) in groundwater and associated soil sediment samples in study area is found to be 0.12 and 8.5 ppm respectively. On the average concentration of copper in groundwater is much lower than associated soil sediment samples (Table-XVIII).

Zinc :

Concentration of zinc in groundwater (Fig. 66) and associated soil sediment (Fig. 67) samples in the districts of Saharanpur,

Muzaffarnagar, Meerut, and Bulandshahr is 3.60, 2.42, 4.02 and 5.73 ppm and 4.29, 0.42, 0.96 and 2.73 ppm respectively. Maximum concentration of zinc in both groundwater (5.73 ppm) and soil samples (4.29 ppm) are obtained at Bulandshahr and Saharanpur respectively, whereas minimum (2.42 ppm) and (0.42 ppm) at Muzaffarnagar respectively.

Average concentration of zinc (Fig. 68) in groundwater and associated soil sediment samples in the study area is 3.8 and 2.2 ppm respectively. It reveals that groundwater samples have higher average concentration than those of soil sediment samples (Table-XVIII).

Nickel :

Concentration of nickel in groundwater (Fig. 66) and associated soil sediment samples (Fig. 67) in the districts of Saharanpur, Muzaffarnagar, Meerut and Bulandshahr is 2.70, 0.94, 1.15 and 1.70 ppm and 13.43, 9.83, 9.83 and 14.85 ppm respectively. Maximum concentration of nickel in both groundwater (2.7 ppm) and soil samples (14.85 ppm) are obtained at Saharanpur and Bulandshahr and minimum (0.94 ppm) and (9.83 ppm) at Muzaffarnagar respectively.

Average concentration of nickel (Fig. 68) in groundwater and associated soil sediment samples is 1.5 and 11.6 ppm respectively.

On the whole, soil sediment samples have significantly higher concentration of nickel than those of groundwater samples at the same locality (Table-XVIII) in the area studied.

Cobalt :

Concentration of cobalt in groundwater (Fig. 66) and associated soil sediment (Fig. 67) samples in the districts of Saharanpur, Muzaffarnagar, Meerut and Bulandshahr is 0.18, 0.40, 0.35 and 0.31 ppm and 0.40, 0.41, 0.33 and 0.40 ppm respectively. It reveals that there is no much variation in the concentration range of cobalt in water and soil sediment samples.

Average concentration of cobalt (Fig. 68) in groundwater and associated soil sediment samples is 0.27 and 0.35 ppm respectively. Average concentration of cobalt in soil sediment samples is slightly higher than those of groundwater samples (Table-XVIII) in this area.

Lead :

Concentration of lead in groundwater (Fig. 66) and associated soil sediment samples (Fig. 67) is 0.02, 0.04, 0.22 and 0.23 ppm and 3.12, 1.15, 1.15 and 2.95 ppm in the districts of Saharanpur, Muzaffarnagar, Meerut and Bulandshahr respectively. Maximum (0.23 ppm) and minimum (0.02 ppm) concentration of lead

in groundwater samples is determined at Bulandshahr and Saharanpur districts respectively. Maximum (3.12 ppm) and minimum (1.15 ppm) concentration of lead in soil sediment samples on the other is obtained at Saharanpur and Muzaffarnagar districts respectively. Data of soil sediment samples have significantly higher concentration of lead than those of groundwater samples in all these districts.

Average concentration of lead (Fig. 68) in area in groundwater and associated soil sediment samples is 0.11 and 1.6 ppm respectively (Table-XVIII). It reveals that soil sediment samples have a quite high concentration of lead at all the sampling stations.

Manganese :

Manganese concentration in groundwater (Fig. 66) and associated soil sediment (Fig. 67) samples is found to be 0.66, 6.51, 0.67 and 0.28 ppm and 5.07, 5.09, 4.83 and 5.07 ppm respectively in Saharanpur, Muzaffarnagar, Meerut and Bulandshahr districts. Groundwater samples in the districts of Muzaffarnagar reveal maximum concentration (6.51 ppm) of manganese and a minimum (0.28 ppm) content of Mn is obtained at Bulandshahr (hand pump). Concentration of manganese does not show much variation in soil sediment samples at various sampling stations.

Average concentration of manganese (Fig. 68) in the study area in groundwater and associated soil sediment samples is 2.7 and 4.9 ppm respectively (Table-XVIII). Soil sediment samples have much higher average concentration of manganese than associated water bodies of the same district.

Chromium :

Concentration of chromium in groundwater (Fig. 66) and associated soil sediment (Fig. 67) samples is 0.39, 0.29, 0.13 and 0.87 ppm and 0.03, 0.04, 0.03 and 0.03 ppm respectively in Saharanpur, Muzaffarnagar, Meerut and Bulandshahr district. Concentration range of chromium in groundwater and soil sediment samples varies from 0.13 to 0.87 ppm and 0.03 to 0.04 ppm respectively. All soil samples have approximately equal concentration range of chromium at all the sampling stations in the study area.

Average concentration of chromium (Fig. 68) on the whole in the area studied, in groundwater and associated soil sediment samples found to be 0.34 and 0.03 ppm respectively (Table-XVIII). All the groundwater samples have much higher concentration of chromium than soil sediment samples.

Cadmium :

Concentration of cadmium in groundwater (Fig. 66) samples is found to be 0.03, 0.15, 0.02 and 0.03 ppm in Saharanpur, Muzaffarnagar, Meerut and Bulandshahr districts respectively. Groundwater samples in Muzaffarnagar have higher concentration of cadmium than the groundwater samples analysed from different places. Maximum concentration range (0.01 to 0.02 ppm) of cadmium in soil sediment samples (Fig. 67) is obtained in Bulandshahr district whereas rest of the soil samples do not show any significant content.

Average concentration of cadmium (Fig. 68) in groundwater and soil sediment samples in the area 0.03 and 0.005 ppm respectively (Table-XVIII). Groundwater samples, on the whole have quite higher concentration of cadmium than those of associated soil sediment samples in the study area.

DISCUSSION :

The agro-indsutrial belt of Ganga-Yamuna doab accommodates a wide variety of various industries namely, dairy and mill products, paper and paper products, hydrogenated oils, various sugar factories and mills, soap and detergents, refractories; paints and pigments, varnishes, drugs and chemicals, vegetable

oils, ferrous and non-ferrous metal foundries, dry and wet batteries, stonewares and asbestos, organic and inorganic chemicals, medicines, tobacco products and alcohols, rubber and plastic to ferromanganese metal alloys in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr. Due to their nearness to the capital city of Delhi, Meerut and Ghaziabad are highly industrialized districts in the Ganga-Yamuna doab. Besides enormous industrial development, various fertilizers, possible soil amendments, organo-phosphate pesticides, insecticides which are applied to increase the crop yield and agricultural land development in the area, substantial amount of these may eventually leach to the groundwater or drain to the river by irrigation return flows. Therefore, all these industrial waste effluents, municipal wastes, i.e. domestic and urban sewage wastes, agricultural wastes, i.e. irrigation return flows, animal wastes, fertilizers, pesticides and their indiscriminate disposal on open land are the principal sources that cause river and soil pollution in the study area. Various liquid or solid waste effluents are directly or indirectly discharged onto land and rivers through open drain and sewage lines, resulted heavy metal pollution in Ganga, Kali, Hindon and Yamuna river waters and their adsorption and settlement in bottom soil sediments, result in the soil pollution of the region.

The total average concentration of nine heavy metals, i.e. Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr and Cd in Yamuna river water (YR.W.) and associated soil sediment (S) samples is found to be in the following order.

YR.W. - Zn> Mn> Fe> Ni> Cr> Cu> Co> Pb> Cd
YR.S. - Ni> Fe> Mn> Cu> Pb> Zn> Co> Cr> Cd

Average concentration of Zn, Mn, Fe and Ni is higher than Cr, Cu, Co, Pb and Cd in all the samples collected from the Yamuna river waters. Maximum concentration of Zn (7.18 ppm), Ni (2.8 ppm), Mn (7.8 ppm), Fe (10.47 ppm), Co (0.32 ppm) and Cu (0.59 ppm) is at Delhi Yamuna bridge, whereas lead (0.20 ppm) is noticed at Baghpat in Meerut district. Maximum concentration of cadmium (0.05 ppm) and chromium (1.29 ppm) on the other is occurred at Bulandshahr and Meerut (Chhaprauli) districts respectively. Average content of Zn (3.97 ppm), Cu (0.17 ppm), Co (0.13 ppm), Pb (0.11 ppm), and Cd (0.02 ppm) in Yamuna river water samples is found to be well within the maximum permissible limits as recommended by W.H.O. European (Zn 5.0 ppm, Cu 3.0 ppm, Pb 0.3 ppm and Cd 0.05 ppm); W.H.O. International (Zn 5 to 15 ppm and Cu 1.5 ppm); USEPA (Zn 5.0 and Cu 1.00 ppm); ISI (Pb 0.1 ppm); ICMR (Cu 1 to 3 ppm) NTAC (Cu 1.00 ppm and Zn 5.0 ppm) and other organisations. The average content of Ni

(1.59 ppm), Mn (3.9 ppm), Fe (3.54 ppm) and Cr (0.56 ppm) in these waters is significantly higher than the above prescribed limits for these metals.

Yamuna river soil sediment samples have higher average concentration of Ni, Fe, Mn and Cu in comparison to Pb, Zn, Co, Cr and Cd. Maximum concentration of Ni (12.72 ppm), Fe (12.01 ppm), Cu (5.56 ppm) is obtained at Delhi Yamuna bridge, whereas highest concentration of Pb (2.91 ppm), Co (0.54 ppm) and Cr (0.06 ppm) is found at Kairana in district Muzaffarnagar. Maximum concentration of Mn (6.79 ppm), Zn (3.93 ppm) and Cd (0.07 ppm) is revealed by the samples collected from Sarsawa (Saharanpur), Baraut (Meerut) and Narora (Bulandshahr) districts respectively. Concentration of cadmium is well below the detectable limits at most of the sampling stations. Average content of Fe (5.1 ppm), Cu (1.28 ppm), Zn (0.99 ppm), Co (0.33 ppm), Cr (0.02 ppm), Cd (0.006 ppm) and Pb (1.15 ppm) in soil sediment samples of Yamuna river, is well within the maximum recommended permissible limits of FWPCF (Fe 15.0, Cu 5.0, Zn 10.0, Co 10.0, Cd 0.05 and Pb 10.0 ppm) and Ayers and Branson (Fe 15.0, Cu 5.0, Zn 10.0, Co 5.0, Cd 0.05, and Pb 10 ppm), whereas average concentration of Ni (11.2 ppm) is significantly higher than the recommended limits by FWPCF (2.0 ppm) and Ayers and Branson (2.0 ppm). Average concentration of Mn (5.01 ppm) slightly exceeds FWPCF (5.0 ppm) limits but lower is than Ayers and

Branson (10.0 ppm). Concentration range of Fe, Cu, Zn, Co, Cr, Cd and Pb and Mn will thus may not produce any significant harmful effects to various crops grown in the area but higher concentration of Ni may be harmful to certain crops.

From the above discussion, it is clear that Yamuna river soil samples have higher average concentration of Fe, Cu, Ni, Pb, Mn and Co than water samples, whereas concentration of Zn, Cr and Cd is higher in water samples as compared to soil samples. Because water of Yamuna river is slightly alkaline and having high organic contents, hence the hydroxides of these metals are precipitated and sink down into bottom sediments. Concentration of Ni, Fe, Mn and Cr is maximum and higher than permissible limits at Yamuna bridge and Meerut because Mn and Fe are extensively used in manufacturing of ferro-manganese alloys and steel, whereas Ni, Cr and Pb in paint and pigment industries. High contents are also due to the industrial and sewage effluents and high petrol vehicles in these districts of study area.

The total average concentration of trace metals i.e. Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr, Cd in Hindon river water (HR.W.) and associated soil sediment (S) samples occurs in the following order.

HR.W. - Fe> Mn> Zn> Ni> Cr> Cu> Cd> Pb> Co

HR.S. - Ni> Mn> Fe> Zn> Cu> Pb> Co> Cr> Cd

Fe (10.72 ppm), Mn (7.33 ppm), Ni (2.6 ppm) have maximum concentration which occurs at Saharanpur near Star Paper Mill, whereas Zn (6.38 ppm) also occurs in higher amount at Ghaziabad city, in comparison to other associated trace metals in Hindon river waters. Highest concentration of Cr (0.93 ppm) and Pb (0.15 ppm) is obtained at Baghpat in district Meerut, whereas maximum concentration of Cu (0.36 ppm) and Cd (0.39 ppm) is found at Burhana in Muzaffarnagar and of Co (0.43 ppm) near Bhayla village in Saharanpur districts. Average concentration of Fe (5.29 ppm), Mn (5.28 ppm) and Cr (0.31 ppm) is significantly higher than the recommended maximum permissible limits by W.H.O. International (Fe 1.0 ppm, Mn, 0.5 ppm and Cr 0.05 ppm); USEPA (Fe 0.3 ppm, Mn 0.05 ppm and Cr 0.05 ppm); ICMR (Fe 0.3 ppm and Mn 0.1 ppm); ISI and NTAC (Fe 0.03 ppm and Mn 0.05 ppm). Cu concentration is found to be well within the permissible limit as recommended by W.H.O. (3.0 ppm); W.H.O. International (1.5 ppm); USEPA (1.0 ppm); AWWA (0.2 ppm) and NTAC (1.0 ppm) whereas Cd is much higher than recommended permissible limit by W.H.O. (0.05 ppm); W.H.O. International (0.01 ppm); USEPA (0.01 ppm) and ICMR (0.01 ppm). Average concentration of Pb (0.09 ppm) exceeds the maximum recommended limits of USEPA (0.05 ppm); ICMR (0.01 ppm); NTAC (0.05 ppm) but lower than W.H.O. (0.3 ppm) and ISI (0.1 ppm). The concentration of Zn (4.29 ppm), Ni (1.32 ppm) and Co (0.07 ppm), on the other is well within the permissible limits of W.H.O. (Zn 5.0 ppm); W.H.O. International (Zn 5 to 15 ppm) and USEPA (Zn 5.0 ppm).

Ni, Mn and Fe metals are present in larger amount as compared to other trace metals (Zn, Cu, Pb, Co, Cr and Cd) in soil sediment samples of Hindon river. Maximum concentration of Fe (4.01 ppm) and Mn (6.57 ppm) is noticed at Ghaziabad city and Muzaffarnagar (Burhana) respectively and of Ni (12.18 ppm) at Charthawal in district Muzaffarnagar. Maximum concentration of Cu (3.47 ppm) and Co (0.37 ppm) in soil sediment samples is found at Ghaziabad and Meerut (Baghpat) whereas Pb (1.40 ppm) and Zn (2.63 ppm) is obtained at Bhayla in district Saharanpur. There is no much variation in the concentration range of Cr (0.01 to 0.4 ppm) and Cd is well below the detectable limit at most of the sampling stations in the districts of Dehradun, Muzaffarnagar and Bulandshahr. Average concentration of Ni (10.28 ppm) and Mn (5.06 ppm) in soil sediment samples of Hindon river is significantly above the maximum recommended limits for the same by FWPCF (Ni 2.0 ppm and Mn 5.0 ppm); Ayers and Branson (Ni 2.0 ppm and Mn 10.0 ppm), whereas average concentration of Fe (2.33 ppm), Zn (1.81 ppm), Cu (0.76 ppm), Pb (0.68 ppm) and Co (0.11 ppm) is well within the maximum recommended permissible limits by FWPCF (Fe 15, Zn 10, Cu 5.0, Pb 10.0, Co 10.0 ppm) and Ayers and Branson (Fe 15, Zn 10.0, Cu 5.0, Pb 10.0 and Co 5.0) in associated soils of Hindon river. Average concentration of chromium (0.02 ppm) and Cd (0.02 ppm) is much below the recommended limits by FWPCF (Cr 20.0 and Cd 0.05 ppm) and Ayers and Branson (Cr 1.0 ppm and Cd 0.05 ppm) in the soil sediment samples of river Hindon.

Average range of Ni, Cu, Pb and Co is higher in soil samples and Fe, Zn, Cr, Mn and Cd is higher in water samples as compared to each other. High content in soil sediment is due to high organic load. Concentration of Fe, Mn, Ni and Cr is maximum and much above the permissible limits in districts of Saharanpur and Ghaziabad. Waste effluents of paper and textile mills, ferro-manganese alloys, paints and pigments and chemicals manufacturing industries besides the large number of sugar factories are the prime sources of metal pollution. High levels of Pb are due to petrol vehicles, lead dust fall out, municipal and industrial waste discharges etc. Agricultural run-off is also importance source because river is flowing through intensively cultivated area.

The average concentration of trace metals in Kali-Nadi river water (KR.W.) and associated soil sediment (S) samples occurs in the following order.

KR.W. - Zn> Fe > Mn > Ni > Cr > Co > Cu > Pb > Cd

KR.S. - Ni> Fe> Mn> Cu> Zn> Pb> Co> Cr> Cd

It reveals that Zn, Fe and Mn occurs in maximum amounts in Kali-Nadi water samples. Maximum concentration of Zn (6.23 ppm), Fe (10.45 ppm) and Mn (7.65 ppm) in river water is found at Bulandshahr city, Cr (1.08 ppm), Co (0.33 ppm) and

Cd (0.08 ppm) near Parikshitgarh in Meerut, Pb (0.11 ppm), Cu (0.25 ppm) and Ni (4.2 ppm) near Incholi village in Muzaffarnagar districts. Average value of zinc (4.27 ppm) is slightly lower than the maximum permissible limits suggested by USEPA (5.0 ppm); W.H.O. European (5.0 ppm); W.H.O. International (5 to 15 ppm) and NTAC (5.0 ppm) but higher than AWWA (1.00 ppm), whereas Fe concentration (3.75 ppm) is much higher than the recommended limits of 0.3 ppm, 1.00 ppm and 0.05 ppm by USEPA; W.H.O. International and AWWA respectively. Average value of Mn (3.6 ppm) is significantly higher than the recommended values by USEPA (0.05 ppm), W.H.O. (0.1 ppm), W.H.O. International (0.5 ppm), NTAC (0.05 ppm), AWWA (0.001 ppm) whereas the concentration of Ni (1.7 ppm) is slightly lower than the recommended value by FWPCF and Ayers and Branson (0.5 to 2 ppm). Average concentration of Cr (0.30 ppm) is much higher than maximum permissible limits by USEPA (0.05 ppm) and W.H.O. (0.05 ppm) whereas the average concentration of cobalt is much below the than recommended value (0.20 ppm). Average concentration of Pb (0.08 ppm) which is lower than ISI (0.1 ppm) and W.H.O. (0.3 ppm) but higher than USEPA (0.05 ppm); W.H.O. International (0.05 ppm); ICMR (0.01 ppm) and NTAC (0.05 ppm), whereas the concentration of Cu (0.12 ppm) is lower than USEPA (1.00 ppm); W.H.O. (3.00 ppm); W.H.O. International (1.5 ppm) and NTAC (1.00 ppm) but above than AWWA (0.2 ppm). Average concentration of Cd (0.02 ppm) is lower than W.H.O. (0.05 ppm) but above than USEPA (0.01 ppm); W.H.O. International (0.01 ppm) and ICMR (0.01 ppm).

Like Kali river water samples, associated soil sediment samples also have higher concentration of Ni, Fe and Mn followed by Cu, Zn, Pb and Co and Cr and Cd is found to be well below the detectable limits at most of the sampling stations along Kali river. Maximum concentration of Ni (13.83 ppm), Fe (12.01 ppm) and Cu (9.73 ppm) in soil sediment samples of Kali river is noticed at Bulandshahr city, Pb (2.7 ppm) and Co (0.47 ppm) at Garh-route in district Meerut and Mn (6.63 ppm) and Zn (2.05 ppm) at Muzaffarnagar (near Shamli bus stand) and at Saharanpur (Bhagwanpur) districts respectively. The concentration of chromium and cadmium is found to be below the detectable limits at most of the sampling stations.

Average concentration of Ni (11.07 ppm) in soil sediments of Kali river, is much higher than the recommended limits in irrigation waters for continuous use by FWPCF and Ayers and Branson and as such will be injurious to plants. Average concentration of Mn, Cu, Zn and Pb is well below the prescribed limits, recommended by FWPCF and Ayers and Branson and as such will not produce any toxic effects on plants. Average concentration of cobalt (0.20 ppm) and cadmium (0.0005 ppm) is nearly equal to the recommended limits.

Average content of Ni, Fe, Mn, Cu, Pb and Co is significantly higher in soil samples as compared to water samples due to alkaline nature of river water. Concentration of Fe, Mn, Ni,

Pb and Cr is maximum and exceeds the recommended limits in districts of Meerut and Bulandshahr. Because these metals are extensively used in manufacturing of ferromanganese alloys, paints and pigments etc. Large number of sugar factories and agricultural activities also add major part of pollution into the river Kali.

The average concentration of heavy metals in Ganga river water (GR.W.) and associated soil sediment (S) samples occurs in the following order.

GR.W. - Fe> Zn> Mn> Ni> Cr> Co> Cu> Pb> Cd
GR.S. - Ni> Mn> Fe> Cu> Zn> Pb> Co> Cr> Cd

Average concentration of Fe, Zn, Mn is maximum in Ganga river water samples. Maximum concentration of Fe (11.90 ppm), Mn (5.9 ppm), Zn (6.36 ppm) and Cr (1.21 ppm) is obtained at Narora in district Bulandshahr, Mn (7.47 ppm) and Pb (0.36 ppm) at Raibala in Dehradun; Ni (2.9 ppm), Cu (0.42 ppm); Cd (0.50 ppm) at Garhmukhteshwar in district Meerut and Co (0.48 ppm) at Sultanpur village in district Saharanpur.

Average concentration of Fe (6.88 ppm) is significantly higher than recommended limits of USEPA (0.3 ppm); W.H.O. European (0.3 ppm); W.H.O. International (1.00 ppm); AWWA (0.05 ppm);

ICMR (0.3 ppm) and NTAC (0.03 ppm). Average concentration of Zn (4.7 ppm) is well within the permissible limits recommended by USEPA (5.0 ppm); W.H.O. (5.0 ppm); W.H.O. International (5 to 15 ppm) and NTAC (5.0 ppm), whereas, it is higher than AWWA (1.0 ppm) limits. Average concentration of Mn (2.15 ppm) and Ni (1.33 ppm) is much above the recommended limits of USEPA (0.05 ppm); W.H.O. (0.1 ppm); W.H.O. International (0.5 ppm); AWWA (0.001 ppm); ICMR, NTAC and EEC (0.05 ppm). Average concentration of Cr (0.52 ppm) is much above the permissible limits of USEPA (0.05 ppm); W.H.O. (0.05 ppm); W.H.O. International (0.05 ppm) and EEC (0.05 ppm) for potable waters, whereas, there is no recommended limit for cobalt in potable waters, but for livestock it is 1.0 ppm. Average content of Cu (0.14 ppm) in these waters is much below the permissible recommended limits by USEPA (1.00 ppm); W.H.O. (3.00 ppm); W.H.O. International (1.5 ppm); AWWA (0.2 ppm); NTAC (1.00 ppm) and ICMR (1 to 3 ppm), whereas average concentration of Pb (0.09 ppm) is slightly higher than USEPA (0.05 ppm); EEC (0.05 ppm); W.H.O. International (0.05 ppm); ICMR (0.01 ppm) and NTAC (0.05 ppm) recommended limits but below the ISI (0.1 ppm) and W.H.O. European (0.3 ppm). Average content of Cd (0.07 ppm) is quite above the recommended limits by USEPA (0.01 ppm); W.H.O. (0.05 ppm); W.H.O. International (0.01 ppm); ICMR (0.01 ppm) and EEC (0.005 ppm).

Maximum concentration of Ni (14.35 ppm) and Pb (3.09 ppm) in soil sediment samples is found at Hardwar and Raibala respectively in district Dehradun; Fe (10.82 ppm) and Cu (11.79 ppm) at Ramghat in Bulandshahr, Mn (6.72 ppm) and Zn (11.72 ppm) at Muzaffarnagar and Cobalt (1.06 ppm) at Sultanpur in district Saharanpur. There is much variation in the concentration range of Cr (0.01 to 0.05 ppm) at most of sampling points by districts of Muzaffarnagar, Meerut and Ghaziabad on the whole, have maximum content of Cr in soil sediment samples, whereas the average concentration of Cd is undetectable at most of the sampling stations and its maximum content is found at Ramghat in Bulandshahr district (0.32 ppm).

The average concentration of Ni (10.85 ppm) is soil sediment samples is significantly higher than the recommended limits by FWPCF and Ayers and Branson. Both FWPCF and Ayers and Branson recommended the upper limit of 2.00 ppm of Ni for short term in fine textural soils, whereas there is a continuous use of soil, it is 0.5 ppm (FWPCF) and 0.2 ppm (Ayers and Branson). Average content of Mn (4.78 ppm) in soil sediment samples is higher than the recommended limits by FWPCF (2.0 ppm) and Ayers and Branson (0.2 ppm) for the continuous use in soils, whereas their concentration is well within the permissible limit for fine textural soils as recommended by FWPCF (5.0 ppm) and Ayers and Branson (10.0 ppm). Average Fe (3.77 ppm) is well below the

recommended limits by Ayers and Branson for continuous use (5.0 ppm) and fine textural soils (15 ppm). Average content of Cu (3.26 ppm) is well below the limits recommended by FWPCF and Ayers and Branson for short time in fine textural soils (5.0 ppm), whereas it is much above the recommended limits for continuous use in all soils (0.20 ppm). Average content of zinc (1.37 ppm) is well below the maximum permissible recommended limits by FWPCF (for continuous use, 5 ppm and for fine textural soils, 10 ppm) and Ayers and Branson (2 to 10 ppm). Ganga river soils reveal that zinc concentration are well within the permissible limits of FWPCF and Ayers and Branson. Average concentration of Pb (0.94 ppm) is well below the maximum permissible limit, therefore as per above recommendations, lead content will not produce any harmful effect on plants, grown within the area. Cobalt content (0.29 ppm) in Ganga river soil sediment samples is below the maximum permissible limits, recommended by FWPCF (10 ppm) and Ayers and Branson (5.0 ppm) for short term use in fine textural soils, whereas concentration is above the recommended limits of FWPCF (0.20 ppm) and Ayers and Branson (0.05 ppm) for continuous use in all soils. Concentration of Cr (0.025 ppm) is well below the recommended permissible limits by FWPCF (5 to 20 ppm) and Ayers and Branson (0.1 to 1.0 ppm) for all soils. Average content of Cd (0.02 ppm) in soils is well within the recommended permissible limits of FWPCF (0.05 ppm) and Ayers and Branson (0.05 ppm).

Soil samples have higher concentration of Ni, Mn, Cu, Pb and Co as compared to water samples, due to alkaline nature of river water together with high organic matter and calcium carbonate solution. Maximum concentration of Fe, Cu, Zn, Mn, Cr and Cd is noticed in districts of Meerut and Bulandshahr whereas Ni is at Muzaffarngar and Co at Saharanpur. Average content of Fe, Mn, Ni and Cr in water and Ni in soil samples is above the permissible limits in districts of Meerut and Bulandshahr. Because metals like Fe, Mn, and Zn are extensively used in manufacturing of ferromanganese alloys and steel, whereas Ni, Cr and Pb are used in paints and pigments, petro-chemical, electroplating-polishing, printing and textile industries etc. Detergents, dairy and food processing, domestic and agricultural wastes together with animal and human excreta, radioactive wastes, bathing ghats and burnt bodies are also important sources of metal pollution in the area studied.

Average concentration of trace metals in groundwater (G.W.) and associated soil sediment (S) samples occurs in the following order.

G.W. - ZN$\rangle$ Mn$\rangle$ Fe$\rangle$ Ni$\rangle$ Co$\rangle$ Cr$\rangle$ Cu$\rangle$ Pb$\rangle$ Cd

G.S. - Ni$\rangle$ Cu$\rangle$ Mn$\rangle$ Zn$\rangle$ Pb$\rangle$ Fe$\rangle$ Co$\rangle$ Cr$\rangle$ Cd

Average Zn (3.8 ppm) and Co (0.27 ppm) in groundwater samples is well within the permissible limits recommended by USEPA;

W.H.O.; W.H.O. International and ICMR. Average concentration of Cu (0.12 ppm) is much below the recommended limits of USEPA (1.0 ppm); W.H.O. European (3.00 ppm); W.H.O. International (1.5 ppm) and AWWA (0.2 ppm) in groundwater samples. Average concentration of Pb (0.11 ppm) and Cd (0.03 ppm) is below the recommended limits of W.H.O. European (Pb 0.3 ppm and Cd 0.05 ppm) but much above the USEPA (Pb 0.05 ppm and Cd 0.01 ppm); W.H.O. International (Pb 0.05 ppm and Cd 0.01 ppm); ICMR (Cd 0.01 ppm and Pb 0.01 ppm); NTAC (Pb 0.05)and EEC (Pb 0.05 ppm and Cd 0.005 ppm). On the other hand average content of Fe (2.0 ppm), Ni (1.5 ppm), Mn (2.7 ppm) and Cr (0.34 ppm) exceeds the recommended limits of USEPA; W.H.O.; W.H.O. International; AWWA; ICMR; ISI and EEC etc. in groundwater samples in the study area.

Average content of Mn (4.9 ppm), Zn (2.2 ppm), Pb (1.6 ppm), Fe (1.5 ppm), Co (0.35 ppm), Cr (0.03 ppm) and Cd (0.0005 ppm) in associated soil sediment samples is well below the limits recommended by FWPCF and Ayers and Branson and as such will not produce any toxic effect to plants, whereas the concentration of Ni (11.6 ppm) and Cu (8.5 ppm) is much above the recommended limits of FWPCF and Ayers and Branson in the soil sediments.

Average content of Ni, Cu, Mn, Pb and Co is found to be higher in soil sediment samples as compared to groundwater. Both

groundwater and associated soil samples have highest concentration of Mn and minimum of Cd at most of the sampling stations. Concentration ranges of Fe, Mn and Cr are found to be higher than permissible limits in groundwater samples of districts Saharanpur, Bulandshahr and Muzaffarnagar.

Municipal, industrial and agricultural waste and wastewaters and their disposal, dumping and land filling are prime sources of groundwater pollution in the study region. Sewer leakage, septic tanks and soak pits (contain organic chemicals, trace metals, i.e. Cr, Cd, Co, Cu, Fe and Mn etc.) may pollute the groundwater. Excessive consumption of fertilizers and pesticides together with human and animal excreta are the most troublesome sources of groundwater pollution. Metals like Fe, Mn and Cr are extensively used in manufacturing of paints and pigments, ferro-manganese alloys and in textile tanning industries.

Polluted effluents from the industrial plants poured deep down through soak pits may pollute the aquifer and difficult to clean, posing a great health hazard problem, especially in central Ganga alluvial plain.

Fe is essential nutrient for human, animal and plants. However, excessive concentration in water can discolour the clothes or cause excessive bacterial activity in pipes (Red rot disease).

Cr and Mn are essential to mammals, however, harmful effects are produced at higher level such as respiratory illness and bad health in area studied.

CONCLUSION :

Concentrations of Cu (0.95 ppm), Fe (10.47 ppm), Ni (2.8 ppm), Zn (7.18 ppm), Mn (7.8 ppm), Pb (0.20 ppm), Co (0.32 ppm) and Cr (1.29 ppm) in water and Ni (12.72 ppm), Fe (12.01 ppm), Cu (5.56 ppm), Pb (2.91 ppm) and Zn (3.93 ppm) in associated soil samples of Yamuna river are found to be maximum at Delhi Yamuna bridge, Meerut and Saharanpur districts. Yamuna river soil samples have higher average concentration of Fe (5.1 ppm), Cu (1.28 ppm), Ni (11.2 ppm), Pb (1.15 ppm), Mn (5.01 ppm) and Co (0.33 ppm) and water samples have higher average concentration of Zn (3.97 ppm), Cr (0.56 ppm) and Cd (0.02 ppm) as compared to each other. Average content of Mn (3.9 ppm), Fe (3.54 ppm) and Cr (0.56 ppm) in water and Ni (11.2 ppm) in associated soils is significantly higher than permissible limits as recommended by various organisations.

Concentrations of Fe (10.72 ppm), Mn (7.33 ppm), Ni (2.6 ppm), Zn (6.38 ppm), Cr (0.93 ppm) and Pb (0.15 ppm) in water and Fe (4.01 ppm), Mn (6.57 ppm), Cu (3.47 ppm), Pb (1.40 ppm) and Zn (2.63 ppm) in associated soil samples of Hindon river are obtained to be maximum in Ghaziabad, Meerut and Saharanpur

districts. Average range of Ni (10.28 ppm), Cu (0.76 ppm), Pb (0.68 ppm) and Co (0.11 ppm) is higher in soil samples as compared to river water samples, whereas average content of Fe (5.29 ppm), Mn (5.28 ppm), Zn (4.29 ppm), Cr (0.31 ppm) and Cd (0.17 ppm) is higher in water samples as compared to soil samples. Concentration ranges of Fe (5.29 ppm), Mn (5.28 ppm) and Cr (0.31 ppm) in water and Ni (10.28 ppm) in soil samples are much above the permissible limits in Hindon river basin.

Maximum contents of Zn (6.23 ppm), Fe (10.45 ppm), Mn (7.65 ppm), Cr (1.08 ppm) and Co (0.33 ppm) in water and Ni (13.83 ppm), Fe (12.01 ppm)and Cu (9.73 ppm) in soils are noticed at Meerut and Bulandshahr districts but Pb and Cr contents are found below the detectable limits. Average value of Ni (11.07 ppm), Fe (4.97 ppm), Mn (4.8 ppm), Cu (2.59 ppm), Pb (0.7 ppm) and Co (0.20 ppm) in soil samples and Zn (4.27 ppm), Cr (0.3 ppm) and Cd (0.02 ppm) in water samples of Kali-nadi is found to be higher as compared to each other. Average concentration ranges of Mn (3.6 ppm), Fe (3.75 ppm) and Cr (0.3 ppm) in water and Ni (11.07 ppm) in soil samples exceed the permissible limits in Kali river basin.

Concentration ranges of Fe (11.9 ppm), Zn (6.36 ppm), Cr (1.21 ppm) and Cu (0.42 ppm) in water samples and Fe (10.82 ppm) and Cu (11.79 ppm) in associated soil samples of Ganga

river are found to be maximum in districts of Meerut and Bulandshahr of study area. Average concentration of Ni (10.85 ppm), Mn (4.78 ppm), Cu (3.26 ppm), Pb (0.94 ppm) and Co (0.29 ppm) is significantly higher in soil samples as compared to water samples, whereas Fe (6.88 ppm), Zn (4.7 ppm), Cr (0.52 ppm) and Cd (0.07 ppm) is higher in water samples as compared to soil samples. Average concentration of Fe (6.99 ppm), Mn (2.15 ppm) and Cr (0.52 ppm) in water and Ni (10.85 ppm) in soil samples is above the recommended limits in districts of Meerut and Bulandshahr.

Average content of Ni (11.6 ppm), Cu (8.5 ppm), Mn (4.9 ppm), Co (0.35 ppm) and Pb (1.6 ppm) is found to be higher in soil samples as compared to groundwater samples. Average concentration of Fe (2.0 ppm), Mn (2.7 ppm) and Cr (0.34 ppm) in ground water and Ni (11.6 ppm) and Cu (8.5 ppm) in soils is much above the permissible limits in districts of Saharanpur, Bulandshahr and Muzaffarnagar.

Concentration of trace metals is usually found to be higher at downstream as compared to upstream of a river. Majority of the surface water samples have higher concentration of trace metals as compared to ground water samples. Average concentration of Ni, Cu, Pb, Co, Fe and Mn is found to be higher in soil samples than water samples. On the average, concentrations of Cu, Zn, Co, Pb and Cd are well within the permissible limits in water and soil samples, whereas concentration of Fe, Mn, and Cr is found to be much higher than the prescribed limits for potable waters but much lower than the permissible limits for soils and Ni content

is noticed to be higher than recommended limits in both water and soil samples of the study area.

High content of metals in soil sediment are due to alkaline nature of water, high organic carbon and calcium carbonate solutions, under these conditions hydroxides of these metals are precipitated and sink down into bottom sediments.

Concentration ranges of Fe, Mn, Cr and Ni are much above the permissible limits in water and soil samples of area studied. Because Fe and Mn metals are extensively used in the manufacturing of ferromanganese alloys and steels, whereas Ni and Cr metals and their compounds are used in manufacturing of paint and pigment industries, printing and textile industries, electroplating-polishing and food processing plants etc. Municipal, industrial and agricultural wastes and wastewaters and their disposal,dumping and land filling are the prime sources of pollution in the study area. Large number of sugar factories, textile and paper mills and various chemical manufacturing plants and radioactive plant add major part of the pollution in Ganga, Yamuna, Hindon and Kali rivers of the area studied.

However, excessive concentrations of Fe in water may discolour the clothes or cause excessive bacterial activity in pipes. Cr and Mn are essential to mammals, however, harmful effects are produced at higher levels such as respiratory illness and bad health in area studied.

The following remedial measures are to be suggested in order to

prevent and minimize water and soil pollution in the area.

1. Location of industrial plants and place of their waste disposal should be in more scientific manner and away from the cities for proper water management and prevention of surface and subsurface water and soil pollution.

2. Leachate from the landfill may be minimize if water can be kept away from the fill material. Material should be filled in a deep water table areas because shallow water table aquifer is more prone to pollution in alluvial formations of Ganga basin.

3. Unscientific and excessive consumption of fertilizers and pesticides should be minimized, because small concentration of these adversely affect the human health and aquatic biota.

4. Domestic and industrial sewer leakage, proper construction of soak pits and septic tanks should be checked properly.

5. Prolonged application of municipal and industrial waste and wastewaters may increase the toxicity of soils due to accumulation of various heavy metals, nitrate and sodium, etc. So proper selection of crops and management of land application system is of prime importance in order to minimize the environmental hazards and maintain the soil potential for crop production and waste assimilation.

6. Human excreta (viruses, bacteria and protozoa) is the principal vehicle for transmission and spread of wide range of communicable diseases, i.e. anaemia, dysentery, abdominal pain and diarrhoea etc. Therefore, collection, transportation, treatment and disposal of human excreta are of the utmost importance in protection of health in any community.

7. Various treatment plants are to be set up in a way to control industrial and sewage wastewater pollution.

8. Pollutants in water tend to be removed by using the various treatment mechanism include, filtration, sorption, sedimentation, precipitation, sterilization, chemical and biological processes, etc.

Table-I : Various Drinking Water Standards for Trace Metals

Elements ppm	U.S.E.P.A. (1962) Max. permissible limit	W.H.O. European (1961) Max. permibble limit	W.H.O. International (1963) Max. permibble limit	A.W.W.A. (1968) Max. permibble limit
Cadmium	0.01	0.05	0.01	-
Chromium	0.05	0.05	0.05	-
Copper	1.00	3.00	1.50	0.20
Iron	0.30	0.1-0.3	1.00	0.05
Lead	0.05	0.30	0.05	-
Manganese	0.05	0.10	0.50	0.001
Zinc	5.00	5.00	5-15	1.00

USEPA - United States Environmental Protection Agency

WHO - World Health Organisation

AWWA - American Water Works Association

Table-II : Trace Elements Tolerance limit of Irrigational Water as proposed by Federal Water Pollution Control Federation (1968) and Ayers and Branson (1975).

Elements ppm	Water use (FWPCF, 1968)		Water use (Ayers and Branson, 1976	
	Continuous	Short term textured soils	Continuous	Short term in fine textured soils
Copper	0.20	5.0	0.20	5.0
Iron	-	-	5.00	15.0
Manganese	2.00	5.0	0.20	10.0
Nickel	0.50	2.0	0.20	2.0
Zinc	5.00	10.0	2.00	10.0
Cadmium	0.005	0.05	0.01	0.05
Cobalt	0.20	10.0	0.05	5.00
Lead	5.00	10.0	5.00	10.00
Chromium	5.00	20.0	0.10	1.00

Table-III : Guidelines for Water Quality Criteria (Neimanis, et al., 1979).

Parameter ppm	Irrigation (all soils)	Livestock	Aquatic life	Potable (Human)		
				EEC	WHO	ICMR
Cadmium	0.05	0.05	0.0012	0.005	0.01	-
Chromium	1.00	1.00	0.10	0.05	-	-
Cobalt	5.00	1.00	-	-	-	-
Copper	5.00	0.50	0.005	0.10	1.50	3.00
Iron	20.00	10.00	1.00	0.20	1.00	0.30
Lead	10.00	0.10	0.03	0.05	0.05	0.10
Manganese	10.00	-	0.02	0.05	0.50	0.05
Nickel	2.00	-	0.025	-	-	-
Zinc	10.00	25.00	0.03	0.10	5-15	-

CHAPTER IX

DEFICIENCY AND TOXIC SYMPTOMS OF TRACE METALS IN PLANTS

CHAPTER-IX

DEFICIENCY AND TOXIC SYMPTOMS OF TRACE METALS IN PLANTS

INTRODUCTION :

Apart from useful function of major ions, importance of some metals, although in very small amount, are now being recognised as profoundly beneficial to crops for proper growth of plants at their different stages. These metals are known as minor or trace metals/elements. The trace metals such as B, Cu, Zn, Fe, Mn, Ni, Co, Cd, Pb, Cr, etc. are now being considered to be essential for proper growth of the plants. However, their metabolic role towards plants nutrition are yet to be emphasized with complete awareness. Experimental evidences reveal that concentration of a particular micronutrient, exceeding needed amount, is highly detrimental to plant causing complete damage or poor yield. Soils and irrigation water are main sources of these trace metals (Israili, 1978, 1980; Khan, 1983; Siddiqi, 1983 and Das, et al., 1983). At low concentrations, some of these elements may prove beneficial to plants, continuous use of irrigation waters containing these elements may eventually result in their accumulation in the soils to levels at which they may prove injurious to plants. Further some elements like

cadmium, though not directly toxic to plants at low concentrations, may nevertheless accumulate in the crops to such an extent as to be toxic to human beings and animals taking those plants (Israili, 1978; Handa, 1983). Deficiencies of 20-24 elements in animal and man (Frieden, 1972) and 13 to 18 elements in plants have recognized (Epstein, 1965). In the present chapter, deficiency and toxic symptoms in the study area, with respect to trace metals, such as iron, copper, zinc, manganese, nickel, cobalt, lead, chromium and cadmium are described. Alluvial soils are the main horizons in this area and at places there are alkali and saline soils also which are locally known as Usar soils. Rice, sugarcane, wheat, various pulses and vegetables are main crops grown within the area.

Pioneering investigation on trace elements were performed by Raulin, 1870; Hudig, 1911; Sommer and Lipman, 1926; Shkalnik, 1935; Ermolenko, 1960, etc. They proved that in some soils, despite the addition of adequate amount of NPK fertilizers, good crops are never produced, or the plants are affected by various non-parasitic diseases such as chlorosis, necrosis, morphological abnormalities, etc., due to shortage of some essential micro-elements.

Israili (1979) has described impact of deficiency and toxicity due to micro-elements such as Cu, Mn, B, Zn, Mo and Co, for both animal and plants in western Uttar Pradesh. High content of B

(2.5 ppm), Zn (9 ppm), Cu (15 ppm), Co (10 ppm) is reported in Aligarh and Ghaziabad districts. Schmitt (1976) has studied the maintenance and improvement of soil fertility through the application of macro and trace elements.

Das and Kidwai (1983) have studied the toxic effects of various trace metals on the growth of plants through irrigation water and soil in parts of M.P. and U.P.

DEFICIENCY AND TOXIC SYMPTOMS :

Deficiency symptoms of micro-elements may be real or conditioned and have to be traced to primary causes of mineral deficiency or secondary effects of nutrient interactions. Symptoms of deficiency develop slowly and become more prominent during reproduction and their subsequent development, causing various diseases like necrosis and chlorosis in plants. Lack of micro-elements in general, is reported to have specific effects on vegetal organs, i.e. root, stem and leaves.

Development of toxic and deficiency symptoms in many cases largely depends upon the source of irrigation water, nutrient status of soil, method of application of fertilizers, seasonal conditions, crop requirement and soil type. Such symptoms are first observed on the green foliage and gradually extended to

other plants. In extreme cases, they result in wilting desiccation, drying of foliage, necrosis of leaf-tissues, poor growth and low yield of plants. A list of diseases, caused by toxic amounts of micro-elements is given below.

Diseases caused by Micro-Elements Toxicity :

Name of Disease	Plant affected	Micro-Element
1. Dry rot	Beet	Boron
2. Chlorosis	Citrus	Boron
3. Stem streak necrosis	Potato	Manganese
4. Frenching	Tobacco	Thallium
5. Yellow Branch	Citrus	Chromium
6. Witches Broom	Tea	Chromium

DISCUSSION OF RESULTS :

Iron :

Iron is an essential micronutrient in plants metabolism. Soil contains lot of iron and its deficiency in irrigation water is generally controlled by the soil. However, intake of iron by plants will be made only when it exists in available form.

Iron deficiency is greatly favoured by the presence of excess lime in the soil and giving rise to plant diseases, specially 'chlorosis'.

Average concentrations of iron are within the range of 2.33 to 6.88 ppm but at Bulandshahr it goestup to 12.01 ppm in river water and associated soil sediments of this area. However, results reveal that in all cases the concentration of iron within the permissible limits as recommended by Ayers and Branson (5-15 ppm).

Copper :

Copper is an important plant nutrient. Intake of copper by plants depends on its existence in available form, either in the soil or in irrigation water. If it is present other than available form, plant could not use it and as such it would not create any harmful effect even it presents more than the recommended value. In non-available form, it is strongly absorbed by the soil and does not show any toxic effect. Grain crops suffering from copper deficiency can be identified by an excess of straw in relation to grain yield, greater the copper deficiency lower is the grain yield (Schmitt, 1976).

Average concentration of Cu is in the range of 0.12 to 3.26 ppm in river waters and associated soils in the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr. Both FWPCF and Ayers and Branson recommended same limit i.e. 0.20 to 5.0 ppm, which will not produce any harmful effects on plants, grown within the area.

Zinc :

The biological importance of zinc on plants has been very well recognised during the last few decades. Its mere presence in soil or irrigation water does not mean that metal would be taken up by plants for their nutrition purposes and for that it must be present in the available form. This phenomenon commonly happens in alkaline soils or soil containing high organic matter, phosphate or magnesium clays.

Mottled leaf is considered due to lack of zinc in the soils. First sign of deficiency appears as intervenal chlorosis, abnormal growth, rosetting and result in little leaf or yellow disease of plants. A typical symptom of zinc deficiency is retardation of growth and almost complete cessation of internodal growth. Toxic action of zinc is noticed near factories. Zinc toxicity retards growth and induced chlorosis and necrosis.

Average concentration of zinc (0.99-4.7 ppm) in water and associated soils of study area is well within the permissible limits as recommended by FWPCF (5.0-10 ppm) and Ayers and Branson (2.0-10 ppm) for irrigation water and soils. The available concentration of zinc in soil and water of the study area will not present hence any toxic effect to plants.

Nickel :

Nickel regulates growth and metabolic activity of many plants in various ways. Its presence in low concentration accelerates growth of the young plants during their germination period whereas high concentration has toxic effects. 1.88 ppm of nickel causes spotting and chlorosis of leaves and depression of growth and in some cases 0.59 ppm of nickel induced chlorosis without affecting the growth. High soluble nickel in field causes failure of crops.

In the study area the average content of nickel in water and soil varies from 1.32 to 11.2 ppm, which is much above the recommended value by FWPCF (0.5-2 ppm) and Ayers and Branson (0.2-2.0 ppm) for soils and irrigation waters. So it will produce any harmful effect on plants, grown within the area.

It is therefore essential that proper remedial measures to put down the nickel content well below the permissible limits, be taken in order to check its ill effects.

Manganese :

Manganese behaves similarly as iron and it takes part in redox-reaction. Its deficiency seriously affects the leaves and encouraged the diseases like chlorosis and necrosis. If such type of diseases are noticed, manganese is to be supplied to the plants as remedy. Symptoms of manganese toxicity occur in severe cases, leaves get dry and fall off, affected parts remain brittle, terminal buds become necrotic, and plant die prematurely. Oats and wheat are the crops that are affected most due to deficiency of manganese in the soils (Schmitt, 1976).

Average content of manganese is within the range of 2.15 to 5.28 ppm in water and soils of study area. As such all values are within the permissible limits of FWPCF (2.0-5.0 ppm) and Ayers and Branson (0.2-10.0 ppm), so far available, will not produce any toxic and harmful effect on the crops.

Average concentration of Pb (0.08-1.15 ppm), Cr (0.02-0.56 ppm), Co (0.07-0.33 ppm) and Cd (0.0005-0.17 ppm) is well within the permissible limits as recommended by FWPCF (Pb 5.0-10 ppm, Cr 5-20 ppm, Co 0.2-10 ppm, and Cd 0.005-0.05 ppm) and Ayers and Branson (Pb 5.0-10.0 ppm, Cr 0.1-1.0 ppm, Co 0.05-5.0 ppm and Cd 0.01-0.05 ppm) in different river waters and associated soils of the area studied. These micro-elements thus will not produce any harmful effects to different crops grown in the region.

From the above discussion, it is apparent that the most of waters and associated soils are suitable for their respective uses as regards the trace metal concentrations as per the recommended limits of the Federal Water Pollution Control Federation (1968) and Ayers and Branson (1975). As such they will not produce any toxic effect to plant if irrigation waters are used either continuously or on a short term basis. However, concentration of Ni (14.85 ppm) exceeds much above the recommended limits in soils of Meerut, Bulandshahr and Muzaffarnagar districts and Cd (0.5 ppm) content also exceeds much above the permissible limits in waters of district Meerut. High levels of these metals therefore may produce some toxic effect on plants at their different stages of growth and as such some amendments are to be made to the soils or to the irrigation waters, depending upon the nature of the crops to be produced within the area of study. Farmers are advised to minimise the toxicity of soils due to trace metals by proper management practices like giving prolong rest period, deep ploughing and flooding and to cultivate the most tolerant and semi-tolerant crops like rice, sugarcane, cotton and wheat in the study area.

CHAPTER X

SUMMARY AND CONCLUSION

CHAPTER-X

SUMMARY AND CONCLUSION

Environmental pollution is a pressing problem of vital importance of present decade because it involves the entire ecosystem which deals the study of air, water, soil, energy, animals, plants in relation to human activity, all interact in a complex network. Rapidly increasing industrialization and excessive consumption of various agricultural products released innumerable toxic effluents which enter the body of water and associated soil sediments and adversely affect all the forms of ecological system in varying degree by various trace metals which are the most insidious pollutants because of their non-degradable nature.

The area, under study, occupies the upper Ganga-Yamuna doab of the central alluvial plain comprising the districts of Dehradun, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Bulandshahr of western Uttar Pradesh. The major and the most important rivers flowing the area are the Ganga, Yamuna, Hindon and the Kali and their various tributaries. The alluvial deposits of Ganga-Yamuna doab which are composed of gravel, sand, silt, clay and minerals like reh and nodular kankars, at shallow depth. Alkali and saline soils with reh deposits are spread out over an area of about

50733 hectares in the study area. For the purpose of agriculture, these soils are unsuitable and regarded as a great problem which requires special treatment and management practices for the profitable utilization. Rice, sugarcane, cotton, wheat, maize as well as various pulses and vegetables are usually the main crops grown within the area.

The prime objectives of the present study have been to comprehend the various sources, causes and extent of water and soil pollution as well as their intensity in an area which is not only thickly populated and heavily industrialized but also agriculturally known as very productive bowl of northern India. The suitability and effective remedies of potable and irrigation waters and usar soils may also be worked out to some extent. Various trace metals, e.g. Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr and Cd and commonly found cations, e.g. Na, K, Ca and Mg are determined in surface and subsurface water and associated soil sediment samples which were collected very close to industries.

Various industrial plants located in the region discharge insignificant untreated waste effluents to the extent of about 16655.56 metric tonnes per day into the rivers through open drains and sewage pipes and also on the ground surface which are in the immediate vicinity of these plants. Among these wastes, the significant pollutants like BOD, COD, DO, suspended

solids, oils and greases together with a number of trace metals like Cu, Zn, Cr, Mn, Fe, Cd, etc., subsequently leached down and pollute the surface and groundwater and pose high contamination potentials. The disposal of industrial wastes on the open land should not be allowed in densely populated area and the wastes must be disposed off in the cemented pools. It is, therefore, suggested that a comprehensive report on the resource position, drainage pattern, soil type and chemistry, geology, population pattern, social status and other elements of environmentally compatible micro-level planning of the region has to be prepared before establishing any industrial complex which might help in alleviating the pollution and selecting the proper disposal sites.

The principal sources of water and soil pollution in the study area are municipal, industrial and agricultural wastes, and out of these, agricultural wastes are the most troublesome to control. Average annual consumption of various nutrients and pesticides in the area is 230035 metric tonnes and 13660.58 tonnes respectively, which appears to be quite high and results in severe pollution hazards of various water bodies and make the soil unfit for grainful use. On the whole the consumption of N-fertilizer is greater as compared to other fertilizers. Concentration of nitrate, phosphate and potassium in potable waters is below the maximum admissible limits (NO_3, 50 mg/l and K, 12 mg/l) but nitrate content goes up to 694 mg/l in Meerut district. Greater portion of the agricultural wastes and excessive inputs of these fertilizers and pesticides fall into the Hindon and the Kali

rivers, both of which flow through intensively cultivated area. The excessive use of synthetic fertilizers and pesticides has caused severe blood circulation problems and over poisoning to man in the area studied. Thus better water management and crop rotation practices coupled with proper utilization and avoidance of excessive use of fertilizers and pesticides may lessen the contamination of groundwater, surface water and soils, without affecting the crop yields.

Average concentrations of Na, K, Ca and Mg in river waters and associated soil sediments in the study area range from 46.50 to 50.8 ppm, 5.4 to 7.6 ppm, 175 to 299.4 ppm and 28.5 to 130.7 ppm; and 16.03 to 19.5 ppm, 4.12 to 6.5 ppm, 12.6 to 18.7 ppm and 15.6 to 19.50 ppm respectively. In the groundwaters and associated soil sediments the average concentrations of the elements are 48.0 ppm, 7.0 ppm, 167.7 ppm and 33.6 ppm; and 17.26 ppm, 5.2 ppm, 8.4 ppm and 14.5 ppm respectively. The four elements in river waters and groundwaters (Ca$\rangle$ Mg$\rangle$ Na$\rangle$ K) have higher concentrations as compared to associated soil sediments (Na$\rangle$ Mg$\rangle$ Ca$\rangle$ K). In sum, the average concentrations of Na, K, Ca and Mg in river waters, groundwaters and associated soil sediments in the study area are well within the permissible limits as recommended by ISI, ICMR, WHO and USGS Water Supply for potable water, irrigation water and associated soil sediments (Ca - 200 ppm, Mg - 150 ppm, Na - 200 ppm and K - 10 ppm).

However, in the districts of Meerut, Saharanpur and Bulandshahr, the concentration of Ca as well as Mg exceeds 500 ppm. The abnormally high concentration of Ca and Mg in river water, groundwater and associated soil sediment samples may be attributed to unscientific and excessive use of Ca-fertilizers, return irrigation flows, waste effluents of a large number of sugar factories, paper and textile mills and various chemical manufacturing industries, clay concretion rich in Mg, abundance of carbonate minerals and kankars at shallow depth and alkali and saline soils. Possibility of adsorption and settlement of these cations by soil sediments and subsequently their tendency to leach down to saturated zone, thereby increase concentration of the elements considerably in the subsurface water bodies of the region. Majority of water samples from downstreams have higher concentration of cations as compared to those from upstreams of a river. Concentration of major elements is higher in water and soil samples collected from the sites that are located in the domains of industrialization or other man-made activities.

Sodium adsorption ratios of river waters and associated soil sediments usually vary from 0.69 to 0.76 and 0.75 to 0.93 respectively except in the Yamuna waters at Delhi and Meerut where the ratio exceeds 2.3 due to greater salinity and enhanced industrialization in the region. Since all the values of SAR lie within the range of first class as recommended by US Salinity Board, the water and soil belonging to this class are excellent

and suitable for irrigation purposes. They have also least amount of nutritional hazards to various crops grown within the area. The pH values of water and associated soil sediment samples range from 7.0 to 7.9 and from 7.0 to 7.6 respectively. Minimum pH (6.8) of river waters was recorded at Dehradun and maximum (7.9) at Meerut. Relatively high pH in water samples of the district Meerut may be attributed partly to greater salinity and partly to enhanced industrialization.

A survey of heavy metal concentrations like Fe, Cu, Zn, Ni, Co, Pb, Mn, Cr and Cd in various surface and subsurface water bodies and associated soil sediments of the study area has been of great importance because of their high toxicity and non-degradable nature and their potential to cause various adverse effects in human beings at certain level of exposure and absorption.

The concentration of Fe in river water and associated soil sediment samples ranges between 0.29 and 11.9 ppm and 1.01 and 12.01 ppm with their average values 4.8 ppm and 4.04 ppm respectively, whereas in groundwater and soil samples the element varies in concentration from 0.85 to 2.35 ppm and 1.01 to 2.01 ppm with their average values being 2.0 ppm and 1.5 ppm respectively. The highest concentration of Fe in water (11.90 ppm) and soil samples (12.01 ppm) was recorded in the Bulandshahr district.

Fe contents are recorded much above the permissible limits in river water and groundwater samples collected in Bulandshahr district which is situated in downstreams of the river Ganges of the area studied. These water bodies in the district of Bulandshahr are contaminated with Fe through the discharges released from the units employed in manufacturing of ferro-manganese alloys, steel and paint and pigment industries. Fe in water may discolour the clothes and cause greater bacterial activity in pipe (Red rot disease).

Mn contents in river water, groundwater and associated soil sediment samples vary from 0.01 to 7.93 ppm, 0.07 to 6.51 ppm and 0.08 to 6.79 ppm with their average values being 3.73 ppm, 2.7 ppm and 4.91 ppm respectively. Maximum concentrations of the element in river water (7.93 ppm) and associated soil samples (6.79 ppm) were found in the districts of Saharanpur and Muzaffarnagar respectively. Mn is present in relatively higher amounts (above 4.0 ppm) in river water, groundwater and associated soil sediment samples in the area studied.

Mn concentrations are much above the recommended limits in surface and subsurface water samples in the districts of Saharanpur and Muzaffarnagar because this metal is largely used in manufacturing ferro-manganese alloys and non-ferrous industries. It is also used in manufacturing of paint and pigment, ceramics, food preservatives and dry cell batteries.

Respiratory illness and neurological disorders are common symptoms associated with higher Mn uptake in these districts of the area. Weakness in legs found among the workers engaged in ferrous, dry and wet battery industries in the district Saharanpur in the vicinity of Yamuna and Hindon rivers may be due to Mn poisoning in the area.

Ni contents in river water and associated soil samples vary from 0.2 to 4.2 ppm and 6.8 to 14.35 ppm; and in groundwater and soil samples from 0.94 to 2.70 ppm and 9.83 to 14.85 ppm respectively. On an average Ni is below 1.5 ppm and 11.6 ppm in water and soil samples in the area studied respectively. Water (2.70 ppm) and soil samples (14.85 ppm) have much higher concentration of Ni than the recommended permissible limits in the districts of Saharanpur and Bulandshahr. Because in these districts Ni and their compounds are widely used in electroplating-polishing, paint and pigment manufacturing industries, food processing plants, printing and textile industries which discharged various waste effluents on the ground surface and carried out to rivers through sewage pipes or open drains. Possibility of adsorption and settlement of Ni contents in soil sediments from these effluents and subsequent leaching into groundwater, thereby increasing the Ni contents in water and soil sediments. Production of dermatitis in some workers engaged in electroplating polishing, paint and pigment industries in Saharanpur may be caused by Ni poisoning.

Concentration of Cr in river water and soil samples varies from 0.01 to 1.29 ppm and 0.01 to 0.06 ppm whereas in groundwater and associated soil samples it varies from 0.13 to 0.87 ppm and 0.03 to 0.04 ppm respectively. On the average, Cr in river water, groundwater and associated soil samples is below 0.42 ppm, 0.34 ppm and 0.03 ppm respectively. Maximum Cr content (1.29 ppm) in Yamuna river water was recorded at Meerut and in soil samples (0.06 ppm) at Muzaffarnagar district. In the majority of water and soil samples, Cr was found to be present in negligible amounts.

Maximum chromium content in water samples of the district Meerut may be attributed to manufacturing of refractories, liquid waste effluents from various industries like metal plating, chromium chemical manufacturing plants, dyeing, tanning and paint and pigment, etc. These liquid wastes, which are disposed off through unlined channels to nearby streams resulted in the enrichment of the river water and groundwater by chromium near and away from the discharge points. Respiratory illness and various skin effects are common in Meerut district.

Concentration of Pb in river water and groundwater varies from 0.01 to 0.36 ppm and in associated soil sediment from 0.03 to 3.12 ppm in the area studied. Average contents of the metal in water and soil samples are below 0.11 ppm and 1.6 ppm respectively. The maximum concentration of lead (3.12 ppm) was found in

the soil samples, collected from the districts of Meerut and Saharanpur.

Concentration of Pb in water and soil samples of Meerut and Saharanpur districts above the recommended limits is due to increasing use of the metal in printing, paint and pigment manufacturing industries, storage batteries, potteries, water pipes, solders, etc. Lead particulates are invariably present in the fumes released from automobile vehicles, lead dust fall out, erosion and leaching of soil, municipal and various industrial waste discharges and run-off from streets also contribute some lead to the water bodies of these districts. Pb in human bodies may affect blood, lungs, kidney and damage the central nervous system. Several cases of these damages are noticed to be reported daily in various hospitals and dispansaries of Meerut district.

Cu content in river water and associated soil samples varies between 0.03 and 0.18 ppm and 0.06 and 11.79 ppm with averages of 0.15 ppm and 1.97 ppm respectively but it goes up to 0.42 ppm in water samples of Meerut district and 27.86 ppm in soil samples of Saharanpur district. Cu concentration in groundwater and soil samples varies from 0.07 to 0.15 ppm and 0.17 to 2.86 ppm respectively but it goes up to 17.59 ppm in soil sediment samples of Saharanpur district.

Average content of Cu is much below the prescribed limits in water and soil samples of the area studied but in Meerut and Saharanpur district it goes much above the recommended limits. Districts Meerut and Saharanpur are highly industrialized and contain various industries ranging from sugar factories, paper and textile mills, chemical and metal foundries, etc. This metal is also widely used in manufacturing paint and pigment, household utensils, etc. Waste effluents of these industries may contribute high concentrations of Cu in various water and associated soil bodies of the districts of Meerut and Saharanpur.

Concentration of Zn in river water and soil samples varies from 1.53 to 7.18 ppm and 0.29 to 4.05 ppm, and in groundwater and associated soil samples from 2.42 to 5.73 ppm and 0.42 to 4.49 ppm respectively. Average levels of Zn are below the permissible limits in water (4.3 ppm) and soil (2.2 ppm) samples of the study area. Zinc levels are widely scattered. Maximum values are noticed at Delhi Yamuna bridge (7.18 ppm) and Saharanpur (4.05 ppm) in water and soil samples respectively.

A large number of industries namely sugar factories and refractories, paper and textile mills, paint and pigment manufacturing industries, metal alloys and soap and detergent manufacturing industries and various chemical and drug manufacturing plants discharge their waste effluents on the land surface and into rivers may be the likely sources of

such a high concentration of Zn in water and soil samples of Delhi and Saharanpur.

Cobalt contents in water and associated soil bodies lie in between 0.01 and 0.48 ppm and 0.01 and 1.06 ppm respectively. Highest content of cobalt in river water (0.48 ppm) and soil samples (1.06 ppm) is noticed at Saharanpur, whereas in groundwater and associated soil samples it goes up to 0.41 ppm in district Muzaffarnagar. Average concentrations of Co do not exceed 0.27 ppm and 0.35 ppm in water and soil samples respectively. Cobalt is generally below the detectable limits at most of the sampling sites.

Cobalt content in water and soil samples is much below the permissible limits and maximum value (1.06 ppm) is noticed in the soil samples of district Saharanpur. Both natural and anthropogenic sources such as paper and textile mills, paint and pigment manufacturing plants and detergents and other man-made activities contribute high concentration of this metal to soils of the district Saharanpur.

Cd content is well below from 0.02 ppm in water and soil samples. However, its maximum concentration is up to 0.5 ppm in the Ganga river water of district Meerut. Majority of the samples have Cd below the detectable limits in the study area.

Average content of Cd is well within the maximum permissible limits in water and soil sediment samples of area studied. But in district Meerut it exceeds the prescribed limit because a large number of compounds of this metal are being used in many industrial processes such as, electroplating, manufacturing of paint and pigment and in welding electrodes, etc. The waste effluents of the industries may be disposed off on land surface and into river water by open drains and sewage pipes nearer to the vicinity of these industries. Metal is being absorbed by soil and settle down to bottom sediments and subsequently leach down to groundwater bodies of the region. The symptoms of Cd poisoning such as vomitting, abdominal cramps, headache and shortness of breath are common among the human beings in districts Meerut and Ghaziabad.

Generally, the concentration of trace metals is found to be higher in downstreams as compared to upstreams of a river. Surface water samples have higher contents of trace metals than groundwater samples. Average levels of Ni, Cu, Pb, Co, Fe and Mn are found to be much higher in soil sediment samples than the water samples. High content of these metals in soil sediments is due to alkaline nature of water, high organic carbon and calcium carbonate solutions, under these conditions, hydroxide of these metals are quickly precipitated and sink down into bottom sediments.

On the average, concentrations of Cu, Zn, Co, Pb and Cd are well within the permissible limits as recommended by FWPCF and Ayers and Branson, ICMR, ISI, AWWA, WHO, USEPA, EEC, etc. for water and soils, whereas Fe, Mn and Cr in water are found to be much higher than the prescribed limits for potable water but much lower than the permissible limits for soils. Ni content was found to be higher than the recommended limits in water and soil samples of the area studied.

Analytical results reveal that the concentration of Fe, Zn, Mn, Co, Pb, Cr and Cd in soils and associated water bodies of the area is well within the permissible limits as recommended by FWPCF and Ayers and Branson. As such, they are not expected to cause any toxic effect to various crops which are grown within the area. However, the concentration of Ni (14.85 ppm) and Cd (0.5 ppm) exceeds much above the permissible limits in soils of district Saharanpur and Meerut. Hence, Ni and Cd contents may produce some toxic effects to various organisms and as such, some amendments are to be made either to soils or irrigation waters. The farmers are advised to minimise the toxicity of soils by applying proper management practices such as allowing prolonged rest period to the land, deep ploughing, flooding and cultivating the most tolerant and semi-tolerant crops like, sugarcane, cotton and wheat etc., in the study area.

No single systematic treatment technique has been found to be effective for the removal of all potentially toxic metals from various soils and associated water bodies. Therefore, periodic monitoring of surface and subsurface water and associated soil sediments is of paramount importance to check any further increase of major and trace metal contents from the discharge of various industrial, sewage and agricultural liquid waste effluents and waste waters together with animal and human excreta which is being disposed off through unlined channels to nearby streams and on land surface.

The following control measures are suggested for an urgent action in order to prevent or minimise the possible increasing potential pollutional hazards in the study area.

1. Location of industrial plants and the place of their waste disposal should be away from thickly populated area. Industrial wastes should be disposed off in the cemented pools and complete treatment for the removal of toxic substances be done.

2. Proper selection of crops, adoption of the best industrial and agricultural practices and managing the land application system should be necessary in a way that alleviates the environmental hazards and maintains the soil potential for crop production and waste assimilation.

3. Unscientific and excessive use of Ca-fertilizers should be avoided in the study area.

4. Domestic and industrial sewer leakages and proper construction of soak pits and septic tanks should be checked properly.

5. Collection, transportation, treatment and disposal of human and animal excreta are of the utmost importance in the protection of health from various toxicants.

6. Various treatment plants should be set up to control the industrial and sewage waste water pollution.

7. Pollutants in water may be removed by using the various treatment mechanism including filtration, sorption, sedimentation, precipitation, sterilization, chemical and biological processes, etc.

8. Large tracts of alkali and saline soils in the Ganga basin are the great problem in agriculture. Hence, the most tolerant and semi-tolerant crops like sugarcane, paddy, cotton and barley may be grown to minimise the toxicity of soils in the study area.

9. The waste effluents through pipelines may be channelized from centre of industrial and urban activities to areas inflicted by saline soils after proper experimentation which may help in proper disposal of these wastes and might augment the fertility of these soils.

REFERENCES

REFERENCES

Andrews, J. (1934), Amer. Jour. of Trop. Med. 14 (5), pp. 439.

Anderson, M.S. (1956), Comparative analyses of sewage sludge. Sew. and Indust. Wat. 28, pp. 132-135.

Aggarwal, R.R. and Mehrotra, C.L. (1958), Soil Survey and soil work in U.P.

Anderson, J.R. and Dornbush, J.N. (1967), Influence of sanitary landfill on groundwater quality. Jour. Amer. Wat. Works Assoc., 59, pp. 457.

Aggarwal, R.R. and Gupta, R.K. (1968), Saline and alkali soils in India, ICAR, Tech. Bull. 15.

Angino, E.E., et al. (1974), Wat. Resour. Res. 10, pp. 1187.

Aston, S.R. et al. (1975), Arsenic in stream sediments and waters of south-west England. Sci. Environ. 4, pp. 347-358.

Ayers, R.S. and Branson, R.L. (1975), Guidelines for interpretation of water quality for agriculture. Univ. of California, pp. 13.

American Public Health Association (1975), Standard Methods for Analyses, 14th ed., New York.

Alderfer, R.G. and Lovelace, E. (1977), Relationship between water quality management planning and land use planning, New York, pp. 59.

Aggarwal, M. and Kumar, H.D. (1978), Physico-chemical analysis of mercury polluted effluents. Ind. Jour. Environ. Hlth., 20, pp. 141.

Aggarwal, V.K. and Raj, K.P.S. (1978), Metal contents in drinking water of Cambay. Water, Air and Soil Pollution, 9, pp. 429.

Aggarwal, V.K., et al. (1978), Heavy metal content in water and sediment of Sursagar lake of Baroda, Gujarat. Int. Jour. Environ. Studies, 12, pp. 50.

Arora, R.P.,et al. (1980), Fate of fertilizer nitrogen in multiple croping system, in soil nitrogen as fertilizer or pollutant. FAO/IAEA, Vienna, pp. 3-22.

Ajmal, M., et al. (1982), Quality of Ganga river in U.P. and Bihar,IAWPC, Tech. Ann., IX, pp. 165-166.

Ayyadurai, K. and Krishnaswamy, V. (1984), Mercury pollution in the Cooum river. Nat. Conf. on poll. St. in Maj. Ind. river basins.

Banerjee, B. (1950), Lead poisoning in printing and soldering operations. Proc. Soc. Study, Ind. Med. 24, pp. 179.

Beaver, P.C. (1953), Persistance of hookworm larve in soil. Amer. Jour. Trop. Med. Hyd., pp. 2, 102.

Brooke, M.M., et al. (1955), Amer. Jour. of Hygiene, 62(3), pp. 214.

Bhaskaran, T.M., et al. (1961), Ind. Jour. Med. Res., 48, 70, Wat. Poll. Abstr. 34, 2097.

Bollar and Butler (1966), Quality criteria for agricultural, municipal and industrial purposes by B.K. Handa, Tech. Man. 4, CGWB, Lucknow, U.P.

Balani, S.G., et al. (1967), Chronic manganese poisoning. Jour. Postgr. Med., 13, pp. 116.

Black, C.A. (1968), Hand book of soil plant relationship.

Bower, C.A., et al. (1968), Sodium hazard of irrigation waters. Soil Sci., 106, pp. 29-34.

Biemond, C. (1971), Rhine river pollution studies. Jour. A.W.W.A., vol. 63, pp. 36-40.

Broadbent, F.E. (1973), Factors affecting nitrification-denitrification in soils. Pennsylvania State Univ. Press.

Brough, J.R. and William, A.C. (1974), Air pollution control of an electric furnace steel making shop. Air Pollution Con. Assoc. Pittsbugh, p. 31.

Brown, V.M. (1976), Aspects of heavy metal toxicity in fresh water, pp. 59-75.

Bhargava, D.S. (1977), Water quality in three typical rivers in U.P. - Ganga, Yamuna and Kali, thesis presented to IIT, Kanpur.

Brown, J.R. and Chow, L.Y. (1977), Heavy metal concentration in Ontario fish. Bull. Environ. Cont. Toxcol., pp. 190.

Brown, B.E. (1977), Effect of mine drainage on the river Hayle, Cornwall. Hydrobiologia, 52, pp. 221.

Baier, R.W. and Healy, M.L. (1977), Poisoning and transport of lead in lake Washington Jour. Environ. Qual., 6, pp. 291-296.

Baker, C.W. (1977), Murcury in surface water of seas around the United Kingdom, London, pp. 230-232.

Bhide, W.D. (1982), Disposal and utilization of urban sewage from irrigation - cost benefit. IAWPC, Tech. Ann. IX, pp. 7-15.

Basargekar, S.S. and Balaji, B. (1983), Incineration for pesticides waste disposal. IAWPC. Tech. Ann. X, pp. 177-186.

Badrinath, S.D., et al. (1983), Upgrading and existing wastewater treatment for textile industry. IAWPC, Tech. Ann., X, pp. 30-36.

Bilgrami, K.S. and Munshi, J.S.D. (1984), Effect of industrial and urban pollutants on physico-chemical and biological characters of Ganga river in Bihar. Nat. Conf. on Poll. St. in Maj. Ind. river basins.

Bagde, S.J. (1984), Environmental quality and pollutional assessment. Nat. Conf. on Poll. St. in Maj. Ind. river basins.

Chandler, A.C. (1954), Amer. Jour. of Trop. Med. and Hygiene, 3, pp. 59.

Chaudhuri, N., et al. (1964), Jour. Amer. Wat. Works Assoc., 56, pp. 73.

Chatterji, G.C., et al. (1964), Geology and groundwater resources of the greater Calcutta industrial area, W. Bengal. Bull. Geol. Surv. India, 21, pp. 150.

Chatterji, G.C. (1967), Groundwater resource of India. Bull. Geol. Surv. of Ind. Sur. B. no. 260, pp. 60.

California Deptt. Water Resources (1968), The fate of pesticides applied to irrigated agricultural land. Bull. 174-1, Sacramento, pp. 30.

Cameron, J. (1970), Newzealand, Jour. of Marine and fresh water Res. (414), pp. 431-444.

Chaowdhury, A.N. and Handa, B.K. (1973), High nitrate content of groundwaters in Lonar village, Buldana District, Maharashtra, India.

Craun, G.E. (1971-77), Outbreaks of water-borne disease in the United States. Jour. Amer. Wat. Works Assoc. Colarado.

Clapp, C.E., et al. (1977), Crop yield and water quality after application of sewage sludge to an agricultural watershed. Cornell Agric. Waste Management Conf. Ithaca, N.Y.

Chakraborti, S. and Bhar, S. (1978), Chronic occupational exposure to lead. CLI, Govt. of Ind.

Chandra, S.V., et al. (1980), An exploratory studies of manganese poisoning in welders Clin., Toxicological, pp. 45.

Central board for the prevention and control of water pollution (1982), Basin, Sub-basin inventory of Water pollution : The Ganga basin, part-I, the Yamuna sub-basin, New Delhi, pp: 48-51.

Chakraborty, D. and Chakraborty, R. (1983), Chemicals that pollute the environment. Sci. Report., vol. 21, 9, CSIR, pp. 496-497.

Chakraborty, C.R. and Roy, P.K. (1984), Geochemical studies of groundwater in Hoogly and Burdwan Distt. Nat. Conf. on Poll. St. in Maj. Ind. river basins, pp. 35.

Chopra, S.L. (1984), Chelated micronutrients and effect on soil fertility. Nat. Conf. on Poll. St. in Maj. Ind. river basins.

Chopra, S.L. (1984), Pesticides in soils and plants. Nat. Conf. on Poll. St. in Maj. Ind. river basins.

Dhawan, C.L. (1964), Land reclamation control board of irrigation and power. Pub. No. 43, Vol. III, 1964.

Dean, J.G., et al. (1972), Removing heavy metals from wastewater. Environ. Sci. Tech., 6, pp. 518-522.

Davis, J.C. (1973), Statistics and data analyses in geology. John Wiley, New York.

Derban, L.K.A. (1974), Outbreak of food poisoning due to alkyl-mercury-fungicide. Arch. Environ. Hlth. 28, pp. 49-52.

Duce, R.A., et al. (1975), Atmospheric trace metals at remote northern and southern hemisphere sites - pollution or natural science. 187, pp. 59-61.

Davies, B.E., and Roberts, L.J. (1978), The distribution of heavy metal contaminated soils in north-west Clwyd, Wales. Water, Air and Soil Pollut., 9, 507-518.

Dakshini, K.M.M. and Soni, J.K. (1979), Water quality of sewage drains entering Yamuna in Delhi. Ind. Jour. Environ. Hlth. 21, pp. 354-362.

Das Gupta, S.P. (1980), Atlas of agricultural resources of India. National Atlas and Thematic Mapping Organisation, Govt. of India, Calcutta.

Daneshwar, R.S., et al. (1982), Study of pulp and paper mill

wastewaters from Titaghur paper Mills. IAWPC, Tech. Ann., IX, pp. 54-63.

Das Gupta, S.P. (1982-83), Comprehensive pollution survey and studies of Ganga river basin in W. Bengal by Centre for study of man and environ. New Delhi, pp. 34-42.

Das, D.K. and Kidwai, A.L. (1983), Quality of irrigation water with respect to trace elements in upper catchment of Betwa river basin, M.P. and U.P. Tech. Man. CGWB, Min. of Agr. and Irrig., vol. I, pp. 337.

Das, D.K. (1983), Use of modern analytical instrument in hydro-chemical investigation. CGWB Min. of Agr. and Irrig., vol. I, pp. 355-365.

Desai, R.G. (1984), Environmental hazards - A case study of Sandur mining area. Jour. of Environ. Sci., pp. 19.

Edsall, C.K., et al. (1919), The occurrence, course and prevention of chronic manganese poisoning. Jour. Indust. Hyg., pp. 183.

Eaton, F.M. (1935), Boron in soils and irrigation waters and its impacts on plants. U.S. Deptt. Agric. Tech. Bull. 448, Washington, D.C., pp. 131.

Eaton, F.M. (1950), Significance of carbonate in irrigation waters. Soil Sci., 69, pp. 123-133.

Epstein, E. (1965), Mineral metabolism in plant. Acad. Press, New York, pp. 438-466.

Eshleman, A., et al. (1971), Is mercury from Hawaiian volcanoes a natural source of pollution? Nature (London), 233, pp. 471.

Ellis, B.G. (1974), The soil as a chemical filter. EPA - 660/2-74-003.

FWPCF (1968), Report of Committee on water quality criteria, Washington, D.C., pp. 234.

Frieden, E. (1972), The chemical elements of life Sci. Amer. vol. 227, pp. 52-60.

F.A.O. (1972), Effects of intensive fertilizer use on human environment. F.A.O. Soils Bull. No. 16, pp. 1-360.

Foster, D.H. and Engelbrecht, R.S. (1973), Microbial hazards in disposing of waste water on soil. The Pennsylvania state Univ. Press, EPA-660/2-74-003, pp. 217-220.

Forstner, U., et al. (1974), Experimental mobilization of metals from aquatic sediments. Chem. Geol., 14, pp. 199.

Food and agricultural organisation, crop water requirement (1977), FAO, irrigation and drainage paper, no. 24,

Greenland, D.J. (1962), Denitrification in some tropical soils. Agric. Sci., 58, pp. 277.

Goldwater, L. (1971), Mercury in the environment. Sci. Amer., 224, pp. 15-21.

Goldberg, E.D., et al. (1971), Radioactivity in the marine environment. Washington, D.C. Nat. Acad. Sci.

Gupta, S.R., et al. (1972), Ind. Jour. Med. Res., 60, pp. 1120.

Gardiner, J. (1974), Chemistry of cadmium in natural waters-II. Wat. Res., 8, pp. 157-164.

Geol, D.K. (1983), Pollution of groundwater by potassium in Uttar Pradesh. Tech. Man. CGWB. Min. of Agr. and Irrig., vol. II, pp. 369-379.

Gupta, M.C., et al. (1984), Concentration of potassium and manganese as determinant of shallow aquifer pollution in alluvial tract of U.P. Nat. Conf. on Poll. St. in Maj. Ind. river basins.

Hutchinson, G.E. and Wollack, A. (1940), Studies on Connecticut Lake sediments. Amer. Jour. Sci. 238, pp.493-497.

Hutchinson, G.E., et al. (1943), Chemistry of lake sediments from Indian-Tibet. Amer. Jour. Sci. 241, pp. 533-542.

Handa, B.K. and Maitra, S.R. (1964), Hydrogeological zones of the Panjab. India, Proc. 22, Int. Geol. Cong., pp. 88-101.

Hinesly, T.D. and Jones, R.L. (1974), Biotoxic elements in soils. EPA-660/2-74-003, pp. 215.

Handa, B.K. (1974), Method of collection and analysis of water samples and interpretation of water analysis data. Tech. Man. no. 1, Min., of Irrig. and Agr.,pp. 363.

Hook, J.E., et al. (1974), Effects of land disposal of wastewater on soil phosphorus relations. EPA-660/2-74-003, pp. 179-184.

Handa, B.K. (1974), Environmental Pollution; Occurrence of high nitrate ion concentrations in groundwaters from some part of India. Int. Assoc. Sci. Hydrol. Cong. Montepellier, vol. 10, pp. 80-85.

Handa, B.K. (1975a), Groundwater pollution in India. Nat. Symp. on Hydrol. Univ. of Roorkee, pp. 34-39.

Handa, B.K. (1975b), High nitrate and potassium ions as indicators of groundwater pollution. Int. Symp. on Quality of water, Burlington, Ontario, Canada.

Handa, B.K. (1975c), Natural waters, their geochemistry, pollution and treatment with a chapter on the use of saline waters. Tech. Man. 2, CGWB, Min. of Agr. and Irrig., pp. 1-276.

Hays, B.D. (1976), Potential of parasitic disease transmission with land application of sewage plant effluents and sludges. Wat. Res., pp. 583.

Handa, B.K. (1976), Modern methods of water analysis. Tech. Man. 3, CGWB, Min. of Agr. and Irrig., pp. 1-404.

Handa, B.K. (1977), Potassium and nitrate ions as indicators of groundwater pollution. J.I.P.H.E., India, pp. 58.

Hasan, M.Z. and Pande, B.P. (1978), Comparative study on methods of determinations of lead in drinking water. Ind. Jour. Environ. Health, pp. 121.

Handa, B.K. (1979), Occurrence of strontium, zinc, copper, lithium and lead in rain water over Chandigarh and Lucknow. Ind. Jour. Heredity, pp. 11, 13.

Handa, B.K. (1979), Effects of return irrigation flows from Irrigation land on the chemical composition of groundwater from shallow unconfined aquifers. Proc. Wat. Tech., 6, pp. 337-349.

Handa, B.K., et al. (1980), Pollution of natural waters by PO_4 in U.P., J.I.P.H.E. India, vol. 4, pp. 103-110.

Harrison, R.M., and Laxen, D.P.H. (1980), Metals in the environment. Chem. Br., 16, pp. 316-320.

Handa, B.K., et al. (1981), Pollution of groundwaters in U.P. Tech. Man. CGWB, Min. of Agr. and Irrig., pp. 242.

Harrison, R.M. and Laxen, D.P.H. (1981), Lead pollution causes and control. Chapman and Hall, London.

Handa, B.K., et al. (1982), Water quality for irrigation use in U.P. (1981). Tech. Rept. CGWB, pp. 1-188.

Handa, B.K., et al. (1982), Pollution of groundwaters by nitreates in U.P., IAWPC. Tech. Ann., IX, pp. 95-103.

Handa, B.K., et al. (1982), Eutrophication of Nainital lake. IAWPC. Tech. Ann. IX, pp. 110-120.

Handa, B.K. (1983), Hydrochemical investigation in alluvial formation of U.P. Tech. Rept. CGWB, Min. of Agr. and Irrig., vol. I, pp. 306.

Handa, B.K. (1983), The effect of fertilizer use on groundwater quality in U.P. Tech. Rept. CGWB, Min. of Agr. and Irrig. pp. 415-416.

Handa, B.K., et al. (1983), Pollution of groundwater by chromium in U.P., IAWPC, Tech. Ann., X, pp. 167-176.

Handa, B.K., et al. (1983), Pollution of groundwaters by potassium in U.P., IAWPC, Tech. Ann., X, pp. 177-186.

Handa, B.K. (1983), Occurrence and distribution of trace metals in natural waters of U.P. Tech. Man., CGWB., Min. of Agr. and Irrig., pp. 293-302.

Handa, B.K., et al. (1984), Pollution of Gomti river water in Lucknow (U.P.), Nat. Conf. on Poll. St. in Major Ind. river basins.

Ippal, H.L., et al. (1966), Reclamation of saline-alkali lands, Min. of food and Agr., New Delhi.

ICAR (1970), A guide for estimating irrigation water requirement, Tech. Series no. 2, ICAR, New Delhi.

I.C.M.R. (1975), Water quality standards. Indian Council of Medical Research., Special pub., no. 44, pp. 21.

Israili, S.H. and Khurshid, S. (1978), Hydrochemistry and extent of water pollution in central Ganga river basin and their impact on plants and animals., Proc. Interion. Symp. Environ., pp. 98-107.

Israili, S.H., et al. (1978a), Trace element hydrochemistry of Hindon river basin and their biological effects. Proc. Symp. Environ. Biol., M. Nagar.

Israili, S.H. (1978g), Studies on water pollution in industrial area of Aligarh and their effects on regional biology. Geoviews, vol. 4, pp. 61-71.

Israili, S.H. (1978h), Hydrochemistry of sodium and potassium in surface and subsurface water bodies of western U.P. Int. Symp. Wat. Management, Ahmadabad, pp. 64-72.

Israili, S.H. (1978i), Chemical quality, water pollution and its control in surface and subsurface water bodies of western U.P. Proc. Int. Symp. Water Management, Ahmadabad, pp. 94-104.

Israili, S.H. (1979),Trace element geochemistry of water bodies in western Uttar Pradesh and its impact on regional biology. Sci. and Environ., pp. 11-18.

Indian Standards Institution (1982), Indian Standards tolerance limits for inland and surface water subject to pollution. 15-2296-1982, New Delhi, pp. 3-13.

Iqbal, S.A., et al. (1984), Study of physico-chemical and biological characteristics of river Betwa to assess the quality and pollution levels. Nat. Conf. on poll. st. in Maj. Indian river basins.

Israili, S.H. and Siddiqi, A. (1984), Water pollution studies of the Hindon river basin in Ghaziabad region. Nat. Conf. on poll. st. in Maj. Indian river basins.

Israili, S.H. (1984); Environmental impact assessment of sanitary landfill in high water table area in some parts of Union Territory of Delhi. Nat. Conf. on Poll. St. in Major Indian river basins.

Joshi, R.N. (1982), Treating textile wastes by anaerobic filter process. IAWPC, Tech. Ann. IX, pp. 30-36.

Jain, A., et al. (1984), Effects of industrial waste upon chemical and biological composition of Halali river. Nat. Conf. on Poll. St. in Maj. Indian river basins.

Kanwar, J.S. (1962), Reclamation of saline, alkali soils, amendments, kinds, amounts and costs. IARI, New Delhi.

Kardos, L.T., and Sopper, W.E. (1974), Renovation of municipal wastewater through land disposal by spray irrigation. EPA-660/2-74-003, pp. 131.

Kemp, A.L.W. and Thomas, R.L. (1976), Impact of man's activities on the chemical composition in the sediments of lake Ontario. Wat. Air Soil Pollut., 5, pp. 469-490.

Keeney, W.L., et al. (1976), Water Res., 10, pp. 981-984.

Khanna, S.K., et al. (1976), Metal contaminants in various food colours. Jour. Sci. Agric., 27, pp. 170.

Khapalia, B.S., et al. (1981), Lead in drinking water. Ind. Jour. Environ. Prot., pp. 92-95.

Kumar, A. (1983), Pollution of natural waters by lead in U.P., CGWB, Tech. Man. Min. of Agr. and Irrig.

Kumar, A. (1983), Pollution of groundwaters by nitrates in U.P., Tech. Man., CGWB, Min. of Agr. and Irrig., pp. 427-432.

Khurshid, S. (1984), Occurrence and distribution of heavy metal in drinking water of western Yamuna river basin. Jour. of Ind. Acad. of Geo. Sci., vol. 27, pp. 11.

Khurshid, S. (1984), Industrial pollution - A case study in Union Territory of Delhi. Nat. Conf. on poll. st. in Maj. Indian river basins.

Khurshid, S. and Khan, A.S. (1984), Effects of variations in the levels of trace elements on human beings in western Yamuna river basin. Nat. Conf. on poll. st. in Maj. Indian river basins.

Lemaisture, C.A., et al. (1956), Studies of a water-borne outbreak amoebiasis. Amer. Jour. of Hygiene, 64, pp. 30.

Lahiri, K.K. (1957), Ind. Jour. Derm., 2, pp. 110.

Livingstone, D.A. (1963), Chemical composition of river and lakes. U.S. Geol. Surv. Prof. Paper, 440-G, pp. 64.

Lloyd, R.M. (1965), Factors that affecting the tolerance fish to heavy metal poisoning. Biol. U.S. Deptt. Health, Education and Welfare, pp. 181.

Laszlo, F., et al. (1977), Heavy metal pollution in Sajo river. Proc. Int. Conf. Environ., pp. 923-932.

Mackie, T.T., et al. (1956), Amer. Jour. Trop. Med. and Hyg., 5, 29.

Mokee, J.E. and Wolf, H.W. (1963), Water quality criteria, California state water resources control board. Publ. 3A, 2nd ed.

Mathur, R.P. (1965), Pollutional aspects of Yamuna river at Delhi. Int. Proc. Symp. Wat. Pollut. Cont., vol. 3, CPHERI, Nagar.

Meek, B.D., et al. (1970), Nitrate transformations in a column with controlled water table. Soil Sci. Soc. Amer. Proc. 34, pp. 235.

Mathur, T.N. and Kaur, J. (1972), Amoebiasis as familial infection. Jour. of Phys. of Ind., 20, pp. 692.

Mirvish, S. (1975), Int. Assoc. Wat. Pollut. Res.

Mathur, A.K., et al. (1977), Comparative toxicity of trivalent and hexavalent chromium to rabbits. Toxicology, pp. 8, 53.

Murthy, K.P.R.V., et al. (1977), Seasonal and annual variation of total concentration of air pollution for Visakhapatnum. Ind. Jour. Ecol., vol. 4, p. 1-12.

Murthy, P.S.N., et al. (1978), Distribution of Al, Ti, Mn, Cu and Ni in sediments. Ind. Jour. Mar. Sci., pp. 67.

Mathur, A.K. and Tondon, S.K. (1979), Some biological attractions in early nickel toxicity. Chemosphere, 8, pp. 893.

McNeely, R.N., et al. (1979), Water quality source book. Environ. Canada, pp. 1-89.

Mutlak, S.M., et al. (1980), Water, Air and Soil Pollution.

Misra, S.K. (1980), Nitrates : Mode of occurrence and their possible implication for causation of human cancer and animal death. Sci. of Engg., vol. 33.

Misra, J.N. (1984), Investigation of Ganga river to determine the biological indicators of water quality. Nat. Conf. on Poll. St. in Maj. Indian river basins.

Niyogi, T.P. (1958), Chronic manganese poisoning. Ind. Jour. Indust. Med., 3, pp. 3.

Nilsson, R.Y. and Rannek, J. (1975), Nitrate in drinking water. Deptt. of Land improvement and drainage. Royal Inst. of Tech., pp. 126.

Nordberg, G.F. (1977), Trace element contamination of environment. Sci. Publ. Co.

Nammalwar, P. (1984), Pesticides pollution in marine environment. Sci. Rept., vol. 21, CSIR, pp. 496-497.

Nammalwar, P. (1984), Heavy metal pollution with reference to Hg and Cd in Adyar estuary, Madras. Nat. Conf. on Poll. St. in Maj. Indian river basins.

Otto, G.F. and Spindler, L.A. (1931), Effect of partial sanitation on infestation with intestinal parasites in south-west Virginia. Med. Jour. 23(6), pp. 174.

Olaniya, M.S., et al. (1969), Well water quality in Jaipur city. Environ. Hlth., vol. 11, pp. 378.

Olsen, R. (1972), Effects of intensive fertilizer use on human environment. F.A.O. Soil Bull. No. 16, pp. 15-34.

Oliver, B.G. (1973), Heavy metal levels of Ottawa and Rideau river sediments. Environ. Sci. Technol., 7, pp. 135-137.

Oliver, B.G. and Agemian, H. (1974), Heavy metal in Ottawa and Rideau river sediments. Can. Inland Waters Dir. Rep. Ser. 37, pp. 10.

Olaniya, M.S., et al. (1978), Pollution studies of well waters in sewage farm at Jaipur. Ind. Jour. of Environ. Hlth., vol. 20, pp. 398.

Planning Commission (1933), Study on waste land, including saline-alkali and waterlogged lands and their reclamation measures. Committee on Natural Resources, New Delhi.

Patterson, J.B. (1971), Metal toxicity arising from industry. Technol. Bull. Min. Agric. Fish, Food, 21, pp. 193-207.

Parker, C.R. (1972), Water analysis by atomic absorption spectroscopy. Varian Techtron Pty. Ltd., Australia.

Patrick, F.M. and Loutit, M. (1976), Passage of metals in effluents through bacteria to higher organisms. Wat. Res., 10, pp. 333-335.

Panicker, P.V.R.C. and Krishnamoorth (1978), Elimination of enteric parasites during sewage treatment processes. IAWPC. Tech., Ann. 5, pp. 130.

Pande, J. and Dass, S.M. (1980), Metallic contents in water and sediments of lake Nainital, India. Water, Air and Soil Poll., 13, pp. 1-10.

Pathak, B.D. (1982), Groundwater resources and development potential in India. CGWB, New Delhi.

Pande, S.P. and Hasan, M.Z. (1983), Studies of trace metal in groundwater. Jour. EN., vol. 63, pp. 53-58.

Panicker, P.V.R.C. (1983), Sanitary significance of human enteric parasites. IAWPC, Tech. Ann., X, pp. 157-165.

Quasim, S.R. and Burchinal, J.C. (1970), Leaching from simulated landfills. J.W.P.C.F., 42, pp. 371-379.

Qadri, S.S.H. (1979), Pesticides as environmental agents in India and their biological effects. Proc. Int. Symp. on Envrion. India.

Richards, L.A. (1954), Diagnosis and improvement of saline and alkali soils. Agric. Handbook-60, Deptt. Agric., Washington, D.C.

Rao, M.S.S. and Rao, L. (1954), Handbook of micro-elements nutrition of plants, pp. 31-38.

Russel, E., et al. (1962), Water waste Treat. Jour. 8, pp. 575.

Raheja, P.C. (1966), Soil productivity and crop growth. Asia Publ. Aouse-474.

Rhodes, J.D. and Bernstein, I. (1971), Chemical, physical and biological characteristics of irrigation and soil water. New York, vol. 1, pp. 222.

Rajgopalan, S., et al. (1972), Water Pollution in Gujarat. Sem. on Environ. Hlth., Ahmadabad, pp. 11-12.

Robinson, A.R. (1973), Sediment our greatest pollutant. Oxford Univ. Press., pp. 186-192.

Rajgopalan, S. (1973), Treatment of textile mill waste CPHERI. Tech. Rept.

Rao, K.L. (1975), India's water wealth, its assessment, uses and projection, Orient Longman, New Delhi, pp. 43-70.

Rajindar, K.K. (1978), Air Pollution. Int. Symp. on Environ. Hyderabad, pp. 1-26.

Reddy, M.M. (1979), Environ. Int. 2(1), pp. 9-12.

Romani, R.I.V., et al. (1979), Heavy metals in the aquatic environment of Kalu river. Rept. from Inst. of Sci.,Bombay.

Raman, V., et al. (1982), Rotating biological contactor,anaerobic filter and gross plot sewage treatment.

Raju, K.C.B., et al. (1983), Phosphate concentration in shallow groundwater of A.P. Tech. Report., CGWB, Min. of Agr. and Irrig., vol. II, pp. 392.

Raman, V., et al. (1983), Environmentally compatible approach to land application of sewage of Bombay city. IAWPC, Tech. Ann. X, pp. 121-132.

Raj, M., et al. (1983), Role of boron in deciding the suitability of groundwaters for irrigation. Tech. Man., CGWB, Min. of Agr. and Irrig., vol. I, pp. 257.

Spindler, L.A. (1929), Amer. Jour. Hyg., 10(2), pp. 476.

Sawer, C.N. (1947), Fertilization of lakes by agricultural and urban drainage. Jour. New Engg. Wat. Works Assoc., 61, pp. 109-127.

Subramanyam, P., et al. (1959), Water Poll. Con. Fed., 32, pp. 344.

Singh, V.P., et al. (1969), Algal flora of sewage of U.P. in relation to physico-chemical variables. Environ. Health, 11, pp. 208.

Stumm, W. and Morgan, J.J. (1970), Aquatic chemistry. Wiley-Interscience, New York, pp. 583.

Shimp, N.F., et al. (1971), Environ. Geol. Notes, 41, pp. 25.

Somayajulu, B.L.K. and Rama (1972), Mercury in sea food from the coast of Bombay. Sci. 44, pp. 207.

Sopper, W.E. and Kardos, L.T. (1974), Vegetation responses to irrigation with treated municipal wastewaters. EPA-660/2-74-003, pp. 242-247.

Scienfeld, J.H. (1975), Air pollution. McGraw Hill Book Co., New York.

Sircar, S., et al. (1975), Occupational lead exposure in India. Ind. Jour. Indust. Med., 21, pp. 151.

Shuval, H.I. and Gniener, W. (1975), Nitrate in drinking water, Water. Poll. Res., pp. 233-250.

Schmitt, L. (1976), The maintenance and improvement of soil fertility through the application of macro elements and trace elements. Nat. Resour. and Develop., vol. 4, 30-45.

Singh, B. and Sekhon, G.S. (1977), Some measures of reducing leaching loss of nitrate beyond potential root zone-III. Proper Crop Rotation Plant Soil, vol. 47, pp. 585-587.

Srivastava, K.D. (1978), Eastern Book Co., Lucknow.

Smeets, J. and Amavis, L. (1981), European Communities directives relating to quality of water intended for human consumption. Water, Air and Soil Pollution, vol. 15(4), pp. 483-502.

Sharma, C.B. and Ghose, N.C. (1983), A preliminary laboratory study on the survival of the indicator and pathogenic bacteria in Ganga Water at Patna. Int. Assoc. of Wat. Poll. Res., London.

Sondhi, T.N. (1983), Pollution of natural waters by 'Manganese' in U.P. Tech. Rept., CGWB., Min. of Agr. and Irrig., vol. (II), pp. 335.

Singh, V., et al. (1983), Treatment of Vanaspati ghee plant effluent and recovery of oil. IAWPC, Tech. Ann. X, pp. 39-43.

Sharma, K.D. and Pathak, P.D. (1984), Biological characteristics of Yamuna river water at Agra. Nat. Conf. on Poll. St. in Maj. Indian river basins.

Shkolnik, M.Y.A. (1984), Trace elements in plants. pp. 68-276.

Todd, D.K. (1959), Handbook of groundwater hydrogeology, Wiley Int. (ed.), New York, London, pp. 177-196.

Turner, D.B. (1970), Work book of atmospheric dispersion estimates. Washington, D.C. NAPCA. Publ. No. 999-AP-26.

Thomas, R.L. and Jaquet, J.M. (1976), Mercury in the surficial sediments of lake Eire. Jour. Fish Res. Board Can. 33, pp. 404-412.

Todd, D.K. and McNulty, D.E.O. (1976), Polluted groundwater, Water Information Centre, Port Washington, N.Y., pp. 179.

Taori, K.B., et al. (1983), Dairy wastewater treatment by anaerobic packed bed upflow filter. IAWPC, Tech. Ann. X, pp. 21-29.

Vahrenkamp, H. (1973), Metalle in Lebensprozessen. Chemel Unserer Zeit-7, pp. 97-105.

Venugopal, B., and Lucky, T.D. (1975), Toxicology of non-radioactive heavy metals and their salts, pp. 4-44.

Verma, S.R. and Sharma, V.K. (1984), Survey of Yamuna river and few related drains in Union Territory with reference to pollution. Nat. Conf. on Poll. St. in Major Indian river basins.

Wilcox, L.V. (1955), Classification and use of irrigation waters. US Deptt. Agric. Circ.-969, Washington, D.C., pp. 19.

Wykoff, D.E., et al. (1955), Amer. Jour. Med. Hyg. 4(3), pp. 465.

Williams, J.D.H., et al. (1971), Phosphate in Calcareous lake sediments. Soil. Sci. Amer. Proc., 35, pp. 250-255.

W.H.O. (1971), International Standards for drinking water, Geneva, 3rd ed.

Walker, W. (1973), Where have all the toxic chemicals gone? Groundwater 11, pp. 11-14.

World Bank (1974), Environmental health and human ecologic considerations in economic development project, Washington, D.C., pp. 88-105.

Wood, J.M. (1974), Biological cycles for elements in environment. Sci., 183, pp. 1049-1052.

Walters, L.J., et al. (1974), Occurrence of As, Cd, Co, Cr, Cu, Fe, Hg, Ni, Sb, Zn in lake Erie sediments. Proc., pp. 219-234.

Walter, M.F., et al. (1975), Predicting vertical movement of manurial nitrogen in soil. Trans. ASAE. 18, pp. 100-105.

TABLES

Table-I : Results of Chemical Analysis of Common Cations in Water & Associated Soil Sediment Samples (ppm)

urce & Side	Location	Water sample No.	Water					Soil Sample No.	Soil				
			Na	K	Ca	Mg	pH		Na	K	Ca	Mg	pH
1	2	3	4	5	6	7	8	9	10	11	12	13	14
muna River A	Saharanpur (Rampur)	W_1	72.93	0.16	188.4	32.15	7.6	S_1	19.81	7.44	21.10	35.60	7.30
" "	Saharanpur (Sarsawa)	W_2	35.87	5.40	73.5	44.05	7.3	S_2	20.33	7.79	14.43	1.42	7.20
" "	M. Nagar (Kairana)	W_3	44.38	5.77	59.6	45.35	7.4	S_3	9.85	2.21	13.01	0.76	7.10
" "	Meerut (Chhaprauli)	W_4	24.08	9.53	14.1	327.60	7.2	S_4	18.16	6.21	0.00	19.91	7.22
" "	Meerut (Baraut)	W_5	85.06	8.66	304.2	432.90	7.7	S_5	18.55	4.79	21.04	20.77	7.26
" "	Meerut (Baghpat)	W_6	72.17	15.27	250.1	1.62	7.6	S_6	18.23	5.82	19.77	15.50	7.25
" "	Delhi (Yamuna Bridge)	W_7	97.04	5.20	30.1	376.00	7.8	S_7	19.97	6.07	1.40	23.43	7.25
" "	Bulandshahr(Dankaur)	W_8	29.35	8.12	275.8	11.80	7.2	S_8	10.66	1.72	23.21	40.79	7.10
" "	Bulandshahr(Jewar)	W_9	80.82	4.05	309.6	0.20	7.6	S_9	9.99	1.97	19.95	19.44	7.00
muna River B	Saharanpur(Rampur)	W_{10}	2.02	5.78	13.6	22.23	7.0	S_{10}	20.07	3.99	0.00	25.93	7.20
" "	Saharanpur(Sarsawa)	W_{11}	31.25	13.05	254.0	42.72	7.2	S_{11}	19.02	4.89	22.08	16.34	7.20
" "	M. Nagar (Kairana)	W_{12}	31.37	8.46	426.7	0.35	7.23	S_{12}	15.49	4.88	28.03	12.80	7.15
" "	Meerut (Chhaprauli)	W_{13}	30.70	1.96	284.4	0.10	7.25	S_{13}	19.07	5.05	1.64	18.97	7.20
" "	Meerut (Baraut)	W_{14}	78.10	7.13	263.1	10.34	7.7	S_{14}	21.65	7.13	24.19	15.95	7.25
" "	Meerut (Baghpat)	W_{15}	75.33	6.58	270.7	25.85	7.6	S_{15}	23.08	8.69	21.32	20.11	7.26
" "	Delhi (Yamuna Brdige)	W_{16}	52.60	6.89	34.0	434.0	7.3	S_{16}	21.14	6.96	0.00	19.99	7.25
" "	Bulandshahr (Dankaur)	W_{17}	23.50	9.72	47.3	501.7	7.2	S_{17}	32.15	13.43	0.02	26.60	7.29
" "	Bulandshahr (Jewar)	W_{18}	13.42	5.77	57.2	45.02	7.23	S_{18}	14.39	4.05	1.13	20.03	7.20

1	2	3	4	5	6	7	8	9	10	11	12	13	14
River A	Saharanpur(Star P.Mill)	W_{19}	74.56	4.33	663.3	54.66	7.6	S_{19}	13.78	6.44	26.68	7.72	7.1
"	Saharanpur(Maheshpur)	W_{20}	31.32	0.05	260.0	0.11	7.3	S_{20}	16.09	5.42	0.97	8.84	7.2
"	Saharanpur(Bhayla)	W_{21}	67.22	3.99	242.9	55.00	7.5	S_{21}	10.49	2.63	0.49	0.67	7.1
"	M.Nagar(Charthawal)	W_{22}	40.51	8.11	307.0	0.18	7.35	S_{22}	18.23	4.05	16.46	27.51	7.2
"	M.Nagar (Burhana)	W_{23}	34.27	8.96	317.0	0.98	7.3	S_{23}	14.94	4.38	16.65	13.19	7.2
"	Meerut (Baghpat)	W_{24}	75.01	16.66	68.2	171.10	7.7	S_{24}	16.78	4.35	20.16	37.22	7.2
"	Ghaziabad	W_{25}	29	- -	----	.00	7.3	S_{25}	15.20	2.85	21.99	18.47	7.2
River B	Saharanpur(Star P.Mill)	W_{26}	79.34	17.09	713.2	28.02	7.8	S_{26}	16.03	3.56	22.42	8.36	7.2
"	Saharanpur (Maheshpur)	W_{27}	31.28	7.46	210.0	8.08	7.35	S_{27}	19.99	4.03	0.55	27.28	7.3
"	Saharanpur (Bhayla)	W_{28}	39.79	16.14	288.0	0.68	7.4	S_{28}	16.35	3.81	13.96	13.50	7.3
"	M. Nagar (Charthawal)	W_{29}	39.88	6.55	251.2	4.38	7.4	S_{29}	17.18	4.52	14.25	31.25	7.3
"	M. Nagar (Burhana)	W_{30}	30.41	2.42	385.7	0.38	7.3	S_{30}	15.64	3.93	18.03	10.85	7.2
"	Meerut (Baghpat)	W_{31}	15.77	8.39	66.3	70.20	7.2	S_{31}	17.08	4.67	0.00	13.37	7.2
"	Ghaziabad	W_{32}	63.35	2.45	198.8	2.20	7.6	S_{32}	16.19	4.04	18.32	0.19	7.2
iver A	Saharanpur (Bhagwanpur)	W_{33}	21.53	12.61	43.0	0.18	7.4	S_{33}	19.83	3.19	0.48	26.26	7.4
"	Saharanpur (Deoband)	W_{34}	43.61	7.49	350.8	0.35	7.5	S_{34}	15.30	6.90	27.27	8.10	7.3
"	M. Nagar(Shamli Bus St)	W_{35}	20.38	1.63	70.5	33.83	7.2	S_{35}	17.45	2.41	0.77	13.06	7.2
"	M. Nagar(Incholi vill.)	W_{36}	26.75	0.53	182.5	26.14	7.3	S_{36}	10.78	4.36	14.29	21.13	7.2
"	Meerut(Parikshitgarh)	W_{37}	40.01	9.52	350.5	38.10	7.4	S_{37}	18.58	4.96	23.08	15.29	7.1
"	Meerut (Garh route)	W_{38}	61.37	7.28	499.8	50.69	7.6	S_{38}	22.82	9.23	18.69	14.52	7.3

1	2	3	4	5	6	7	8	9	10	11	12	13	14
River B	Saharanpur (Bhagwanpur)	W_{41}	20.27	3.24	59.8	0.01	7.3	S_{41}	17.42	4.36	0.20	19.70	7.3
"	Saharanpur (Deoband)	W_{42}	21.96	4.51	103.0	0.14	7.3	S_{42}	16.54	5.40	0.70	11.28	7.2
"	M.Nagar(Shamli Bus St.)	W_{43}	44.31	2.80	414.6	57.82	7.5	S_{43}	21.06	5.59	26.29	25.34	7.25
"	M.Nagar(Incholi vill.)	W_{44}	57.78	3.89	510.6	20.97	7.6	S_{44}	18.77	5.00	33.43	20.89	7.3
"	Meerut (Parikshitgarh)	W_{45}	80.53	8.40	569.6	26.32	7.9	S_{45}	17.26	5.32	23.95	12.68	7.2
"	Meerut (Garh route)	W_{46}	92.65	6.86	351.9	41.89	7.9	S_{46}	21.78	6.40	12.66	12.28	7.2
"	Bulandshahr	W_{47}	71.54	4.05	42.8	348.30	7.8	S_{47}	21.51	6.00	0.88	50.01	7.3
"	Bulandshahr (Pahasu)	W_{48}	72.01	11.17	433.3	281.10	7.8	S_{48}	15.41	3.89	26.20	10.99	7.3
"	Bulandshahr (Pahasu)	W_{49}	70.55	17.04	115.7	239.10	7.8	S_{49}	19.04	4.68	17.79	18.23	7.25
River A	Dehradun (Rishikesh)	W_{50}	0.01	0.20	178.9	13.11	6.8	S_{50}	18.72	5.61	22.40	11.22	7.25
"	Dehradun (Raibala)	W_{51}	65.25	0.67	179.1	46.46	7.6	S_{51}	22.16	7.58	21.89	20.15	7.3
"	Dehradun (Hardwar)	W_{52}	49.01	5.00	69.4	4.71	7.4	S_{52}	22.63	10.36	1.12	0.69	7.30
"	Saharanpur(Sultanpur)	W_{53}	54.23	7.37	80.8	4.63	7.5	S_{53}	64.23	31.60	18.69	19.47	7.6
"	M.Nagar (Noka Bridge)	W_{54}	29.90	9.10	134.8	1.22	7.3	S_{54}	18.28	4.80	19.78	14.77	7.2
"	Meerut (Parikshatgarh)	W_{55}	12.76	3.92	203.0	39.56	7.2	S_{55}	12.33	2.92	0.70	10.53	7.2
"	Meerut (Garhmukhteshwar)	W_{56}	00.01	1.78	818.5	140.30	7.0	S_{56}	16.63	5.40	41.16	14.19	7.2
"	Bulandshahr(Anupshahr)	W_{57}	75.57	2.73	292.1	0.10	7.7	S_{57}	15.18	3.79	20.62	9.58	7.2
"	Bulandshahr(Narora)	W_{58}	89.19	8.41	475.8	238.40	7.8	S_{58}	19.23	5.87	27.74	16.30	7.25
"	Bulandshahr (Ramghat)	W_{59}	81.44	2.13	426.7	245.6	7.8	S_{59}	17.01	5.03	23.26	15.46	7.2

1	2	3	4	5	6	7	8	9	10	11	12	13	14
iver B	Dehradun (Rishikesh)	W_{60}	8.60	5.23	13.40	27.25	7.0	S_{60}	11.15	1.77	0.76	19.13	7.2
"	Dehradun (Raibala)	W_{61}	52.47	9.92	59.40	37.95	7.6	S_{61}	17.81	6.12	16.95	78.03	7.3
"	Dehradun (Hardwar)	W_{62}	67.00	2.41	152.10	5.33	7.64	S_{62}	15.78	4.02	22.88	14.74	7.2
"	Saharanpur(Sultanpur)	W_{63}	65.07	10.11	215.80	53.84	7.7	S_{63}	18.12	5.80	15.24	8.79	7.3
"	M.Nagar (Noka Bridge)	W_{64}	24.31	2.83	169.80	1.82	7.2	S_{64}	16.71	4.83	16.13	9.78	7.2
"	Meerut (Parikshatgarh)	W_{65}	32.83	7.84	179.00	0.04	7.3	S_{65}	18.60	3.20	19.50	1.55	7.3
"	Meerut (Garhmukteshwar)	W_{66}	88.53	7.15	71.40	121.30	7.8	S_{66}	17.31	5.47	17.14	21.26	7.2
"	Bulandshahr(Anupshahr)	W_{67}	74.48	14.15	458.7	207.00	7.75	S_{67}	16.46	5.37	22.35	17.94	7.2
"	Bulandshahr(Narora)	W_{68}	62.10	1.04	316.2	174.40	7.75	S_{68}	16.28	4.75	21.88	16.51	7.2
"	Bulandshahr(Ramghat)	W_{69}	24.07	6.98	437.0	1.20	7.22	S_{69}	16.79	6.76	25.38	23.23	7.2
	Saharanpur(Nala)	W_{70}	44.69	7.36	76.7	0.78	7.59	S_{70}	21.63	6.82	0.53	12.56	7.3
Pump	Saharanpur	W_{71}	47.60	7.22	65.2	6.41	7.59	S_{71}	18.77	5.95	0.24	9.09	7.2
"	Muzaffarnagar	W_{72}	37.77	9.49	1.2	0.13	7.56	S_{72}	21.59	8.44	0.58	14.06	7.25
"	Meerut	W_{73}	40.01	6.36	503.5	1.36	7.50	S_{73}	14.98	4.21	23.95	24.25	7.2
"	Bulandshahr(Bus stand)	W_{74}	87.57	2.57	308.4	2.54	7.80	S_{74}	17.21	4.39	24.61	14.74	7.2
"	Bulandshahr(Jewar)	W_{75}	03.53	7.53	51.4	190.70	6.50	S_{75}	9.39	1.35	0.39	12.78	7.1

Table-II : Results of Chemical Analysis of Trace Metal Contents in Water Samples (ppm).

Side	Location	Sample No.	Fe	Cu	Zn	Ni	Co	Pb	Mn	Cr	Cd
	2	3	4	5	6	7	8	9	10	11	12
iver A	Saharanpur (Rampur)	W_1	3.10	0.13	4.00	1.80	0.01	0.11	0.04	0.81	0.01
"	Saharanpur (Sarsawa)	W_2	2.50	0.15	4.33	2.21	0.16	0.10	0.31	1.24	0.01
"	Muzaffarnagar (Kairana)	W_3	3.95	0.20	3.99	1.29	0.28	0.09	1.49	0.80	0.20
"	Meerut (Chhaprauli)	W_4	4.84	0.15	0.00	0.80	0.27	0.16	5.37	1.29	0.04
"	Meerut (Baraut)	W_5	0.81	0.08	6.38	2.26	0.00	0.17	3.45	0.70	0.00
"	Meerut (Baghpat)	W_6	0.73	0.07	4.12	1.04	0.20	0.19	3.51	0.53	0.00
"	Delhi (Yamuna Bridge)	W_7	3.55	0.36	7.18	1.44	0.32	0.07	6.69	0.12	0.02
"	Bulandshahr (Dankaur)	W_8	2.73	0.11	0.00	1.32	0.26	0.11	5.10	0.90	0.05
"	Bulandshahr (Jewar)	W_9	2.89	0.15	1.73	1.64	0.26	0.04	0.33	0.00	0.00
iver B	Saharanpur (Rampur)	W_{10}	1.40	0.15	3.95	2.30	0.05	0.05	5.16	0.36	0.03
"	Saharanpur (Sarsawa)	W_{11}	3.09	0.17	3.87	1.70	0.01	0.03	4.32	0.02	0.01
"	Muzaffarnagar (Kairana)	W_{12}	6.45	0.23	4.43	1.70	0.00	0.02	5.59	0.18	0.00
"	Meerut (Chhaprauli)	W_{13}	1.60	0.12	3.63	2.68	0.03	0.17	4.04	0.77	0.00
"	Meerut (Baraut)	W_{14}	1.06	0.06	4.39	1.64	0.18	0.18	4.13	0.56	0.01
"	Meerut (Baghpat)	W_{15}	1.60	0.06	4.04	0.29	0.11	0.20	3.30	0.17	0.00
"	Delhi (Yamuna Bridge)	W_{16}	10.47	0.59	5.65	2.80	0.05	0.08	7.88	0.40	0.00
"	Bulandshahr (Dankaur)	W_{17}	3.55	0.14	5.67	2.18	0.29	0.12	4.93	1.06	0.05
"	Bulandshahr (Jewar)	W_{18}	10.39	0.21	4.38	0.00	0.08	0.16	5.24	0.28	0.00

	2	3	4	5	6	7	8	9	10	11	12
iver A	Saharanpur (Star Paper Mill)	W_{19}	9.63	0.20	4.22	0.00	0.01	0.05	6.71	0.30	0.01
"	Saharanpur (Maheshpur)	W_{20}	4.86	0.18	4.01	1.20	0.00	0.07	6.36	0.00	0.00
"	Saharanpur (Bhayla)	W_{21}	5.23	0.19	4.64	0.94	0.43	0.05	7.33	0.35	0.00
"	Muzaffarnagar (Charthawal)	W_{22}	3.22	0.36	4.28	1.00	0.03	0.13	6.08	0.54	0.31
"	Muzaffarnagar (Burhana)	W_{23}	2.27	0.15	4.50	2.30	0.00	0.14	6.30	0.37	0.38
"	Meerut (Baghpat)	W_{24}	2.84	0.13	4.82	1.20	0.08	0.15	0.05	0.77	0.40
"	Ghaziabad	W_{25}	4.19	0.10	2.21	1.45	0.12	0.09	3.63	0.32	0.00
iver B	Saharanpur (Star Paper Mill)	W_{26}	10.66	0.19	3.71	2.60	0.00	0.05	5.95	0.00	0.02
"	Saharanpur (Maheshpur)	W_{27}	10.72	0.21	4.39	2.20	0.00	0.05	6.78	0.00	0.18
"	Saharanpur (Bhayla)	W_{28}	10.05	0.22	4.32	2.10	0.00	0.13	6.59	0.05	0.34
"	Muzaffarnagar (Charthawal)	W_{29}	3.51	0.15	4.32	0.80	0.13	0.12	5.99	0.14	0.07
"	Muzaffarnagar (Burhana)	W_{30}	3.73	0.18	4.17	0.20	0.00	0.14	6.23	0.74	0.39
"	Meerut (Baghpat)	W_{31}	2.35	0.12	4.23	1.20	0.14	0.15	5.73	0.93	0.30
"	Ghaziabad	W_{32}	0.66	0.08	6.38	1.94	0.12	0.10	0.34	0.00	0.06
ver A	Saharanpur (Bhagwanpur)	W_{33}	2.40	0.15	2.90	2.80	0.03	0.08	5.29	0.00	0.00
"	Saharanpur (Deoband)	W_{34}	1.16	0.13	1.53	3.70	0.12	0.09	5.08	0.31	0.00
"	Muzaffarnagar (Shamli Bus Stand)	W_{35}	7.03	0.19	4.38	2.00	0.00	0.11	5.73	0.07	0.02
"	Muzaffarnagar (Incholi village)	W_{36}	10.17	0.25	4.02	1.70	0.02	0.12	5.86	0.01	0.06
"	Meerut (Parikshitgarh)	W_{37}	0.93	0.09	4.08	1.55	0.26	0.21	0.12	0.36	0.08
"	Meerut (Garh route)	W_{38}	4.71	0.11	4.06	2.82	0.23	0.01	0.99	0.91	0.00

	2	3	4	5	6	7	8	9	10	11	12
r B	Saharanpur (Bhagwanpur)	W_{41}	5.93	0.16	3.49	0.00	0.00	0.07	6.52	0.11	0.00
"	Saharanpur (Deoband)	W_{42}	3.62	0.14	3.24	0.00	0.03	0.07	5.70	0.27	0.00
"	Muzaffarnagar (Shamli Bus Stand)	W_{43}	3.10	0.18	4.55	4.20	0.00	0.10	3.61	0.11	0.00
"	Muzaffarnagar (Incholi village)	W_{44}	0.82	0.14	4.38	2.00	0.23	0.11	5.37	0.23	0.00
"	Meerut (Parikshitgarh)	W_{45}	2.09	0.09	3.99	1.68	0.33	0.20	5.55	1.08	0.08
"	Meerut (Garh route)	W_{46}	6.85	0.14	4.04	2.85	0.26	0.00	0.00	0.00	0.00
"	Bulandshahr	W_{47}	8.09	0.16	6.10	0.38	0.19	0.11	0.41	0.96	0.08
"	Bulandshahr (Pahasu)	W_{48}	1.18	0.03	5.93	1.48	0.23	0.05	0.24	0.17	0.00
"	Bulandshahr (Pahasu)	W_{49}	0.29	0.04	6.23	0.99	0.09	0.06	7.65	0.67	0.01
r A	Dehradun (Rishikesh)	W_{50}	5.74	0.13	3.74	1.64	0.20	0.00	1.11	0.99	0.01
"	Dehradun (Raibala)	W_{51}	4.47	0.12	4.05	0.86	0.17	0.01	0.29	0.27	0.01
"	Dehradun (Hardwar)	W_{52}	5.08	0.16	4.02	1.42	0.25	0.24	0.47	0.16	0.01
"	Saharanpur (Sultanpur)	W_{53}	8.51	0.14	4.31	1.15	0.48	0.09	0.43	0.46	0.00
"	Muzaffarnagar (Noka Bridge)	W_{54}	3.11	0.12	4.27	0.00	0.02	0.15	3.96	0.31	0.01
"	Meerut (Parikshatgarh)	W_{55}	4.05	0.22	4.35	2.90	0.00	0.17	5.86	0.00	0.00
"	Meerut (Garhmukhteshwar)	W_{56}	10.26	0.07	6.30	1.42	0.14	0.14	3.85	0.00	0.00
"	Bulandshahr (Anupshahr)	W_{57}	7.17	0.04	6.03	2.02	0.10	0.05	2.06	0.25	0.01
"	Bulandshahr (Narora)	W_{58}	7.32	0.09	6.36	1.79	0.03	0.03	1.26	1.02	0.01
"	Bulandshahr (Ramghat)	W_{59}	8.15	0.06	6.06	1.87	0.24	0.02	5.90	0.18	0.03

	2	3	4	5	6	7	8	9	10	11	12
r B	Dehradun (Rishikesh)	W_{60}	2.64	0.25	4.30	1.12	0.25	0.01	0.22	0.56	0.02
"	Dehradun (Raibala)	W_{61}	4.75	0.13	4.38	1.37	0.39	0.36	0.16	0.56	0.00
"	Dehradun (Hardwar)	W_{62}	7.21	0.16	3.53	1.07	0.41	0.07	0.01	0.75	0.00
"	Saharanpur (Sultanpur)	W_{63}	10.33	0.23	3.96	0.26	0.22	0.08	0.01	0.27	0.19
"	Muzaffarnagar (Noka Bridge)	W_{64}	2.67	0.15	4.34	3.50	0.00	0.15	5.36	0.58	0.21
"	Meerut (Parikshatgarh)	W_{65}	3.94	0.17	4.30	1.40	0.03	0.17	4.42	0.00	0.02
"	Meerut (Garhmukteshwar)	W_{66}	10.69	0.42	6.24	1.05	0.28	0.14	0.71	0.96	0.50
"	Bulandshahr (Anupshahr)	W_{67}	10.33	0.04	5.21	1.51	0.28	0.05	0.00	1.14	0.10
"	Bulandshahr (Narora)	W_{68}	11.90	0.15	5.12	1.51	0.33	0.03	0.17	1.21	0.01
"	Bulandshahr (Ramghat)	W_{69}	10.18	0.09	5.00	0.34	0.29	0.01	0.00	0.79	0.31
	Saharanpur(Nala)	W_{70}	3.98	0.17	2.91	1.46	0.32	0.03	7.93	0.50	0.07
	Saharanpur	W_{71}	2.35	0.15	3.60	2.70	0.18	0.02	0.66	0.39	0.03
	Muzaffarnagar	W_{72}	2.23	0.14	2.42	0.94	0.40	0.04	6.51	0.29	0.15
	Meerut	W_{73}	0.85	0.07	4.02	1.15	0.35	0.22	0.67	0.13	0.02
	Bulandshahr (Bus Stand)	W_{74}	0.89	0.09	4.37	1.70	0.31	0.23	0.28	0.00	0.03
	Bulandshahr (Jewar)	W_{75}	1.75	0.08	5.73	1.48	0.10	0.13	0.07	0.87	0.00

Table-III : Results of Chemical Analysis of Trace Metal Contents in Soil Sediment Samples (ppm)

Side	Location	Sample No.	Fe	Cu	Zn	Ni	Co	Pb	Mn	Cr	Cd
	2	3	4	5	6	7	8	9	10	11	12
iver A	Saharanpur (Rampur)	S_1	1.01	0.63	0.29	11.00	0.48	2.19	6.48	0.01	0.00
"	Saharanpur (Sarsawa)	S_2	3.01	1.24	0.40	12.04	0.47	2.91	0.08	0.05	0.00
"	Muzaffarnagar (Kairana)	S_3	2.08	0.90	0.69	10.43	0.54	2.25	1.80	0.06	0.00
"	Meerut (Chhaprauli)	S_4	2.01	1.27	1.26	12.76	0.38	1.21	5.18	0.03	0.02
"	Meerut (Baraut)	S_5	11.01	0.91	1.05	10.80	0.27	2.02	5.20	0.03	0.00
"	Meerut (Baghpat)	S_6	11.01	0.34	1.02	12.64	0.39	1.85	5.12	0.03	0.00
"	Delhi(Yamuna Bridge)	S_7	12.01	5.56	1.91	12.72	0.29	0.53	5.18	0.02	0.01
"	Bulandshahr (Dankaur)	S_8	6.29	0.55	0.23	12.11	0.28	0.03	5.32	0.02	0.00
"	Bulandshahr (Jewar)	S_9	11.01	0.66	0.81	9.02	0.34	1.51	5.16	0.04	0.00
ver B	Saharanpur (Rampur)	S_{10}	1.01	0.09	0.45	11.74	0.08	0.00	6.50	0.01	0.03
"	Saharanpur (Sarsawa)	S_{11}	2.01	0.07	0.38	9.62	0.05	0.00	6.79	0.01	0.00
"	Muzaffarnagar (Kairana)	S_{12}	1.01	0.07	0.54	9.64	0.26	0.71	6.53	0.02	0.02
"	Meerut (Chhaprauli)	S_{13}	2.01	0.65	1.34	6.80	0.38	1.64	5.16	0.03	0.00
"	Meerut (Baraut)	S_{14}	1.01	0.81	3.93	12.24	0.26	0.27	5.06	0.03	0.00
"	Meerut (Baghpat)	S_{15}	1.01	0.92	1.29	12.73	0.37	1.70	5.13	0.03	0.00
"	Delhi (Yamuna Bridge)	S_{16}	7.01	4.62	0.54	11.71	0.23	0.12	5.07	0.02	0.00
"	Bulandshahr (Dankaur)	S_{17}	8.01	3.57	1.25	12.61	0.51	1.69	4.97	0.02	0.07
"	Bulandshahr (Jewar)	S_{18}	10.01	0.39	0.51	11.12	0.51	0.29	5.49	0.03	0.00

2	3	4	5	6	7	8	9	10	11	12
Saharanpur (Star Paper Mill)	S_{19}	2.01	0.17	0.84	9.02	0.00	0.24	5.64	0.01	0.00
Saharanpur (Maheshpur)	S_{20}	2.01	0.19	1.66	11.55	0.03	0.00	5.87	0.02	0.00
Saharanpur (Bhayla)	S_{21}	2.59	1.35	2.63	10.52	0.33	1.40	0.44	0.04	0.00
Muzaffarnagar (Charthawal)	S_{22}	1.09	0.55	0.74	12.18	0.00	1.19	6.30	0.02	0.00
Muzaffarnagar (Burhana)	S_{23}	3.01	0.43	0.44	12.10	0.00	0.72	6.57	0.02	0.00
Meerut (Baghpat)	S_{24}	4.01	0.60	0.92	10.43	0.37	1.04	5.10	0.02	0.03
Ghaziabad	S_{25}	4.01	3.47	0.64	9.18	0.22	0.88	5.16	0.01	0.00
Saharanpur (Star Paper Mill)	S_{26}	1.01	0.06	1.11	10.95	0.12	0.00	5.88	0.01	0.00
Saharanpur (Maheshpur)	S_{27}	1.01	0.14	0.30	8.20	0.00	0.36	6.38	0.02	0.00
Saharanpur (Bhayla)	S_{28}	1.91	0.37	0.63	9.79	0.00	1.04	5.88	0.02	0.00
Muzaffarnagar (Charthawal)	S_{29}	1.01	0.30	2.12	7.82	0.00	0.42	6.48	0.02	0.00
Muzaffarnagar (Burhana)	S_{30}	1.01	0.42	0.46	10.22	0.00	0.54	5.94	0.02	0.38
Meerut (Baghpat)	S_{31}	4.01	0.49	0.96	10.43	0.29	0.97	5.00	0.03	0.00
Ghaziabad	S_{32}	4.01	2.22	0.79	10.97	0.30	0.81	0.26	0.02	0.00
Saharanpur (Bhagwanpur)	S_{33}	1.01	0.22	0.61	10.76	0.00	0.00	6.02	0.02	0.00
Saharanpur (Deoband)	S_{34}	1.91	0.20	0.52	10.83	0.04	0.28	5.79	0.02	0.00
Muzaffarnagar (Shamli Bus Stand)	S_{35}	2.61	0.46	0.76	13.07	0.01	0.43	6.21	0.02	0.00
Muzaffarnagar (Incholi village)	S_{36}	1.61	0.21	0.72	11.44	0.16	0.36	0.21	0.03	0.00
Meerut (Parikshitgarh)	S_{37}	4.01	0.97	0.93	8.79	0.42	1.28	4.97	0.03	0.00
Meerut (Garh route)	S_{38}	4.01	5.47	1.89	11.43	0.25	1.26	4.91	0.04	0.00

	2	3	4	5	6	7	8	9	10	11	12
ver B	Saharanpur (Bhagwanpur)	S_{41}	2.01	0.43	2.05	9.70	0.00	0.06	6.22	0.02	0.00
"	Sahranpur (Deoband)	S_{42}	2.01	0.38	0.55	10.39	0.09	0.00	6.09	0.02	0.00
"	Muzaffarnagar (Shamli Bus Stand)	S_{43}	4.91	0.22	0.39	10.50	0.00	0.27	6.63	0.02	0.00
"	Muzaffarnagar (Incholi village)	S_{44}	4.91	0.57	0.97	12.26	0.07	0.32	6.40	0.02	0.00
"	Meerut (Parikshitgarh)	S_{45}	7.01	0.79	0.87	11.85	0.34	1.23	4.96	0.03	0.00
"	Meerut (Garh route)	S_{46}	7.01	5.24	1.35	7.89	0.47	2.79	5.03	0.04	0.00
"	Bulandshahr	S_{47}	12.01	3.25	0.97	13.83	0.37	0.47	5.45	0.02	0.00
"	Bulandshahr (Pahasu)	S_{48}	10.01	9.73	1.51	9.18	0.22	0.62	4.83	0.01	0.00
"	Bulandshahr (Pahasu)	S_{49}	12.01	7.80	0.52	10.93	0.30	0.75	5.14	0.01	0.00
ver A	Dehradun (Risnikesh)	S_{50}	2.01	0.98	0.91	9.39	0.43	1.34	4.97	0.03	0.00
"	Dehradun (Raibala)	S_{51}	2.47	0.37	0.48	9.69	0.38	1.85	4.83	0.04	0.00
"	Dehradun (Hardwar)	S_{52}	2.01	0.89	0.98	11.46	0.37	0.84	0.26	0.04	0.00
"	Saharanpur (Sultanpur)	S_{53}	2.01	1.64	0.45	9.95	1.06	0.81	5.17	0.05	0.00
"	Muzaffarnagar (Noka Bridge)	S_{54}	3.01	0.38	1.54	10.52	0.00	0.43	6.72	0.03	0.00
"	Meerut (Parikshatgarh)	S_{55}	2.01	0.80	1.46	9.83	0.00	0.28	6.47	0.03	0.00
"	Meerut (Garhmukhteshwar)	S_{56}	3.01	0.42	0.74	10.68	0.23	2.27	4.47	0.02	0.00
"	Bulandshahr (Anupshahr)	S_{57}	7.44	9.69	0.44	9.06	0.34	0.00	5.06	0.01	0.02
"	Bulandshahr (Narora)	S_{58}	7.01	8.73	0.67	9.14	0.25	0.84	5.22	0.01	0.01
"	Bulandshahr (Ramghat)	S_{59}	7.01	3.43	0.89	10.76	0.24	0.54	5.24	0.00	0.06

	2	3	4	5	6	7	8	9	10	11	12
ver B	Dehradun (Rishikesh)	S_{60}	2.01	1.41	0.77	10.01	0.37	1.41	5.03	0.04	0.00
"	Dehradun (Raibala)	S_{61}	2.01	5.85	1.27	12.75	0.43	3.09	5.70	0.04	0.00
"	Dehradun (Hardwar)	S_{62}	2.06	1.28	0.85	14.35	0.41	0.81	5.04	0.05	0.00
"	Saharanpur (Sultanpur)	S_{63}	2.01	0.32	0.24	9.77	0.37	0.95	4.29	0.05	0.00
"	Muzaffarnagar (Noka Bridge)	S_{64}	3.01	0.42	11.72	12.17	0.04	1.12	6.31	0.04	0.00
"	Meerut (Parikshatgarh)	S_{65}	4.01	0.37	0.78	11.77	0.09	0.00	0.35	0.04	0.00
"	Meerut (Garhmukteshwar)	S_{66}	4.63	0.82	1.08	11.53	0.28	0.84	5.14	0.03	0.00
"	Bulandshahr (Anupshahr)	S_{67}	6.01	10.25	0.84	12.27	0.20	0.00	5.24	0.01	0.11
"	Bulandshahr (Narora)	S_{68}	7.01	5.97	0.80	11.89	0.26	0.65	5.26	0.01	0.01
"	Bulandshahr (Ramghat)	S_{69}	10.82	11.79	0.83	10.65	0.11	0.84	5.42	0.01	0.32
	Saharanpur (Nala)	S_{70}	2.01	27.86	4.05	11.43	0.43	1.19	4.83	0.04	0.00
mp	Saharanpur	S_{71}	2.01	17.59	4.29	13.43	0.40	0.12	5.07	0.03	0.00
"	Muzaffarnagar	S_{72}	1.01	1.82	0.42	9.83	0.41	1.15	1.09	0.04	0.00
"	Meerut	S_{73}	2.01	0.17	0.96	9.83	0.33	1.15	4.83	0.03	0.00
"	Bulandshahr (Bus Stand)	S_{74}	2.01	2.86	2.73	14.85	0.40	2.95	5.07	0.03	0.02
"	Bulandshahr (Jewar)	S_{75}	0.00	0.60	0.82	10.73	0.10	0.10	4.88	0.03	0.01

Table - IV : Average concentration of common cations in Water and associated Soil Sediments (ppm)

Name of the River		Water				Soil			
		Na	K	Ca	Mg	Na	K	Ca	Mg
Yamuna River	Side-A	60.19	6.91	167.27	141.30	16.17	4.89	14.88	19.74
	Side-B	37.59	7.26	183.44	120.26	20.67	6.56	10.93	19.64
Hindon River	Side-A	50.34	6.60	297.00	40.86	15.07	4.17	14.77	16.23
	Side-B	42.83	8.64	301.00	16.28	17.03	4.08	12.50	14.97
Kali River	Side-A	42.69	7.20	261.81	89.22	19.69	6.56	16.10	15.09
	Side-B	59.07	6.88	289.03	112.85	18.75	5.18	15.70	20.16
Ganga River	Side-A	45.74	4.10	285.91	73.41	22.64	8.30	19.74	13.24
	Side-B	49.95	6.77	207.28	63.01	16.50	4.81	17.82	21.10

Table-V : Total Average Concentration of Common Cations of both the sides.

Name of the River	Water				Soil			
	Na	k	Ca	Mg	Na	K	Ca	Mg
Yamuna River	48.80	7.00	175.0	130.70	18.4	5.7	12.6	19.50
Hindon River	46.50	7.60	299.4	28.50	16.03	4.12	13.6	15.6
Kali River	50.80	7.04	275.4	101.03	19.2	5.8	15.90	17.6
Ganga River	47.80	5.40	246.5	68.20	19.5	6.5	18.7	17.10

Table-VI : Average concentration of Trace Metals in Water (ppm)

Name of the River		Fe	Cu	Zn	Ni	Co	Pb	Mn	Cr	Cd
Yamuna River	Side-A	2.78	0.15	3.50	1.5	0.19	0.11	2.92	0.71	0.03
	Side-B	4.30	0.19	4.44	1.69	0.08	0.11	4.95	0.42	0.01
Hindon River	Side-A	4.60	0.18	4.09	1.15	0.09	0.09	5.20	0.37	0.15
	Side-B	5.95	0.16	4.50	1.50	0.05	0.10	5.37	0.26	0.20
Kali River	Side-A	4.60	0.13	3.90	2.01	0.14	0.09	3.40	0.23	0.03
	Side-B	2.90	0.12	4.65	1.50	0.15	0.08	3.89	0.40	0.01
Ganga River	Side-A	6.30	0.11	4.90	1.50	0.16	0.09	3.20	0.36	0.009
	Side-B	7.46	0.17	4.60	1.16	0.248	0.107	1.10	0.68	0.13

Table-VII : Average concentration of Trace Metals in Water of both the sides (ppm)

Name of the River	Fe	Cu	Zn	Ni	Co	Pb	Mn	Cr	Cd
Yamuna River	3.54	0.17	3.97	1.59	0.13	0.11	3.90	0.56	0.02
Hindon River	5.29	0.17	4.29	1.32	0.07	0.09	5.28	0.31	0.17
Kali River	3.75	0.12	4.27	1.70	0.14	0.08	3.60	0.30	0.02
Ganga River	6.88	0.14	4.70	1.33	0.20	0.09	2.15	0.52	0.07

Table-VIII : Average concentration of Trace Metals in Soil Sediments (ppm)

Name of the River		Fe	Cu	Zn	Ni	Co	Pb	Mn	Cr	Cd
Yamuna River	Side-A	6.60	1.33	0.85	11.5	0.38	1.60	4.39	0.03	0.003
	Side-B	3.60	1.24	1.13	10.9	0.29	0.71	5.63	0.02	0.01
Hindon River	Side-A	2.63	0.96	1.12	10.8	0.13	0.78	5.01	0.02	0.004
	Side-B	1.99	0.57	0.91	9.76	0.10	0.59	5.11	0.02	0.05
Kali River	Side-A	3.14	2.03	1.00	11.42	0.20	0.69	4.14	0.02	0.001
	Side-B	6.80	3.15	1.02	10.72	0.20	0.72	5.63	0.02	0.00
Ganga River	Side-A	3.79	2.73	0.85	10.0	0.33	0.92	4.86	0.02	0.009
	Side-B	3.75	3.80	1.90	11.7	0.25	0.97	4.7	0.03	0.04

Table-IX : Total Average Concentration of Trace Metals in Soil Sediments (ppm)

Name of the River	Fe	Cu	Zn	Ni	Co	Pb	Mn	Cr	Cd
Yamuna River	5.1	1.28	0.99	11.20	0.33	1.15	5.01	0.02	0.006
Hindon River	2.33	0.76	1.81	10.28	0.11	0.68	5.06	0.02	0.02
Kali River	4.97	2.59	1.01	11.07	0.20	0.70	4.80	0.02	0.0005
Ganga River	3.77	3.26	1.37	10.85	0.29	0.94	4.78	0.025	0.02

Table-X : Common Cations in Water Calculated in Percentage

S.No.	Na	Ca	Mg	Total	Calculated values in % Na	Ca	Mg
1	2	3	4	5	6	7	8
				YAMUNA RIVER WATER			
1.	37.47	101.00	27.19	164.64	22.75	61.34	16.51
2.	33.55	163.75	43.38	240.68	13.93	67.78	18.02
3.	37.80	243.00	22.85	303.65	12.44	80.00	7.52
4.	27.39	149.25	163.85	340.49	8.04	43.76	48.12
5.	81.58	283.65	221.62	586.50	13.90	48.36	37.78
6.	73.72	260.05	13.73	347.50	21.21	74.96	3.95
7.	74.82	32.05	405.00	511.87	14.61	6.26	79.12
8.	26.40	161.55	256.75	444.70	5.93	36.32	57.73
9.	47.12	183.43	222.61	253.16	18.61	72.45	8.93
				HINDON RIVER WATER			
10.	76.95	688.25	41.34	866.54	9.54	85.33	5.12
11.	31.30	235.00	4.09	270.39	11.57	86.90	1.50
12.	53.50	265.45	27.84	346.79	15.42	76.54	8.02
13.	40.19	279.90	2.28	321.57	12.49	86.79	0.70
14.	32.34	351.35	0.68	384.37	8.41	91.40	0.17
15.	45.39	67.25	120.65	233.29	19.45	28.82	51.71
16.	46.41	209.70	3.10	259.21	17.90	80.89	1.19

... contd.

KALI RIVER WATER

1	2	3	4	5	6	7	8
17.	20.90	51.4	0.09	72.39	28.87	71.00	0.72
18.	32.78	226.0	0.24	25.90	12.66	87.26	0.09
19.	32.34	242.5	45.82	320.66	10.08	75.62	14.29
20.	42.26	346.5	23.55	412.31	12.25	84.04	5.71
21.	60.27	460.0	32.21	552.48	10.91	83.26	5.83
22.	77.01	425.4	46.29	548.70	14.03	77.53	8.44
23.	60.27	147.3	345.40	561.57	10.73	26.23	61.51
24.	75.43	389.5	251,50	716.43	10.53	54.37	35.10
25.	70.55	115.7	239.10	425.35	16.59	27.20	56.21

GANGA RIVER WATER

26.	4.30	96.18	20.18	120.66	3.56	79.70	16.72
27.	58.00	119.25	42.20	219.45	26.40	54.34	19.22
28.	58.00	110.75	5.00	173.75	33.38	63.37	2.80
29.	59.65	148.30	29.24	237.19	21.83	62.52	12.32
30.	27.10	152.30	1.47	180.87	14.94	84.20	0.81
31.	22.79	191.00	19.80	233.59	9.70	81.17	8.40
32.	44.27	373.55	130.80	548.62	8.00	68.00	23.84
33.	75.02	375.40	103.00	553.40	13.55	67.83	18.60
34.	75.64	396.00	206.40	678.00	11.15	58.40	30.44
35.	52.75	431.00	123.00	606.75	8.60	71.00	20.27

Table-XI : Common Cations in Soil Sediments calculated in percentage.

S. No.	Na	Ca	Mg	Total	Calculated values in % Na	Ca	Mg
1	2	3	4	5	6	7	8
YAMUNA RIVER SOIL							
1.	19.94	10.55	30.76	61.25	32.55	17.22	50.22
2.	19.67	18.25	8.88	46.80	42.02	38.99	18.97
3.	12.67	20.52	6.78	39.97	34.20	51.33	16.96
4.	18.81	0.82	19.44	39.07	48.14	2.09	49.76
5.	19.90	22.61	18.36	60.87	32.69	37.14	30.16
6.	20.60	20.50	17.80	58.90	34.90	34.80	30.22
7.	50.55	0.70	21.70	72.95	69.29	0.95	29.74
8.	21.40	11.61	33.69	66.70	32.00	17.40	50.50
9.	12.19	10.54	19.75	42.48	28.60	24.80	46.49
HINDON RIVER SOIL							
10.	14.90	24.55	8.04	47.49	31.30	51.60	16.92
11.	18.00	0.76	18.06	36.82	48.80	2.00	49.00
12.	13.42	7.47	7.00	27.89	48.10	26.70	25.00
13.	17.70	15.35	29.39	62.31	28.40	24.60	27.11
14.	15.29	17.34	12.02	44.65	34.20	38.30	26.92
15.	16.93	10.00	25.29	52.22	32.40	19.14	48.40
16.	16.00	20.15	9.33	45.48	35.18	44.30	20.50

KALI RIVER SOIL

1	2	3	4	5	6	7	8
17.	18.62	0.34	22.90	41.86	44.48	1.48	54.70
18.	15.92	13.90	9.69	39.51	40.29	35.10	24.52
19.	19.25	13.53	19.34	52.12	36.93	25.95	37.10
20.	14.77	23.86	21.01	59.64	24.76	40.00	35.22
21.	17.92	23.51	13.98	55.41	32.30	42.42	25.23
22.	22.30	15.67	13.40	51.37	43.41	30.50	26.00
23.	27.98	11.67	25.20	64.85	43.14	17.99	38.85
24.	16.87	23.57	16.48	56.92	29.67	41.40	28.90
25.	19.01	17.79	18.23	55.03	34.54	32.32	33.12

GANGA RIVER SOIL

26.	14.93	11.58	15.17	41.68	35.82	27.78	36.39
27.	19.98	19.42	40.09	88.49	22.57	21.94	35.47
28.	19.20	12.00	7.71	38.91	49.34	30.84	19.81
29.	41.17	16.96	14.13	72.26	56.97	23.47	19.55
30.	17.49	17.95	22.27	57.71	30.30	31.10	38.58
31.	19.25	10.10	6.00	35.35	54.45	28.58	16.97
32.	16.97	29.15	17.72	63.84	26.58	45.66	27.85
33.	15.82	21.48	13.76	51.06	23.98	42.06	26.94
34.	17.84	24.81	16.40	59.05	30.21	42.01	27.77
35.	16.90	24.32	19.34	60.56	27.90	40.15	31.93

Table-XII : Sodium Adsorption Ratio of Yamuna Water & Associated Soil Sediments

Sample No.	Water				Soil			
	Na (epm)	Ca (epm)	Mg (epm)	SAR	Na (epm)	Ca (epm)	Mg (epm)	SAR
1.	1.62	5.05	2.26	0.85	0.86	0.55	2.58	0.68
2.	1.45	8.18	3.60	0.59	0.86	0.90	0.74	0.95
3.	1.62	12.00	1.90	0.62	0.56	1.05	0.58	0.62
4.	1.19	7.45	13.60	0.37	0.82	0.04	1.66	0.91
5.	3.54	14.15	18.81	0.87	0.86	1.13	1.58	0.74
6.	3.20	13.00	1.14	1.23	0.86	1.05	1.50	0.76
7.	3.25	1.60	33.75	0.77	2.21	0.04	1.80	2.30
8.	1.14	8.00	21.33	0.30	0.96	0.58	2.83	0.73
9.	2.00	9.00	1.88	0.86	0.56	0.52	1.66	0.53

Table-XIII : Sodium Adsorption Ratio of Hindon River Water & Associated Soil Sediments

Sample No.	Water				Soil			
	Na (epm)	Ca (epm)	Mg (epm)	SAR	Na (epm)	Ca (epm)	Mg (epm)	SAR
10.	3.34	34.40	3.40	0.77	0.65	1.24	0.66	0.72
11.	1.34	11.75	0.33	0.54	0.78	0.03	1.50	0.89
12.	2.32	13.25	2.33	0.83	0.60	0.37	0.58	0.88
13.	1.70	13.90	0.19	0.65	0.78	0.76	2.44	0.61
14.	1.40	18.55	0.05	0.46	0.69	0.86	1.00	0.76
15.	1.97	3.35	10.00	0.76	0.73	0.50	2.10	0.64
16.	2.00	10.45	0.25	0.86	0.69	1.00	0.77	0.73

Table-XIV : Sodium Adsorption Ratio of Kali River Water and Associated Soil Sediments.

Sample No.	Water				Soil			
	Na (epm)	Ca (epm)	Mg (epm)	SAR	Na (epm)	Ca (epm)	Mg (epm)	SAR
17.	0.86	2.55	0.00	0.76	0.82	0.01	1.92	0.83
18.	1.43	11.30	0.02	0.60	0.69	0.70	0.83	0.86
19.	1.43	12.10	4.56	0.51	0.82	0.70	1.61	0.76
20.	1.83	17.30	1.96	0.59	0.65	1.20	1.75	0.53
21.	2.62	23.00	2.66	0.73	0.78	1.20	1.16	0.72
22.	3.34	21.25	3.83	0.95	0.96	0.80	1.11	0.98
23.	2.26	7.35	28.70	0.53	1.21	0.60	2.08	0.97
24.	3.26	19.50	20.91	0.74	0.73	1.20	1.37	0.64
25.	3.08	5.78	24.40	0.81	0.82	0.90	1.50	0.75

Table-XV : Sodium Adsorption Ratio of Ganga River Water and Associated Soil Sediments

Sample No.	Water				Soil			
	Na (epm)	Ca (epm)	Mg (epm)	SAR	Na (epm)	Ca (epm)	Mg (epm)	SAR
26.	0.18	4.80	1.66	0.10	0.65	0.57	1.26	0.68
27.	2.52	5.95	3.50	1.16	0.86	0.97	4.08	0.55
28.	2.52	5.50	0.41	1.48	0.83	0.60	0.64	1.06
29.	2.53	7.50	2.40	1.15	1.79	0.85	1.17	1.79
30.	1.17	7.60	0.12	0.59	0.76	0.90	1.85	0.64
31.	1.00	9.55	1.66	0.42	0.83	0.50	0.56	1.17
32.	1.92	18.65	10.80	0.50	0.73	1.45	1.47	0.61
33.	3.26	18.75	8.58	0.88	0.69	1.07	1.16	0.65
34.	3.26	19.80	17.16	0.75	0.78	1.25	1.36	0.68
35.	2.30	21.55	10.25	0.57	0.73	1.21	1.61	0.61

Table-XVI : Average of Sodium Adsorption Ratio of Water and Associated Soil Sediments.

Name of the River	SAR value of the Water	SAR Value of the Soil
Yamuna River	0.71	0.93
Hindon River	0.69	0.75
Kali River	0.69	0.78
Ganga River	0.76	0.94

Table-XVII : Average Concentration of common cations in subsurface water and associated soil sediments (ppm)

Water				Soil			
Na	K	Ca	Mg	Na	K	Ca	Mg
48	7	167.7	33.6	17.26	5.2	8.4	14.5

Table-XVIII : Average concentration of Trace Metal Contents in subsurface water and associated soil sediments(ppm).

	Fe	Cu	Zn	Ni	Co	Pb	Mn	Cr	Cd
Water	2.0	0.12	3.8	1.5	0.27	0.11	2.7	0.34	0.03
Soil	1.5	8.50	2.2	11.6	0.35	1.6	4.9	0.03	0.005

FIGURES

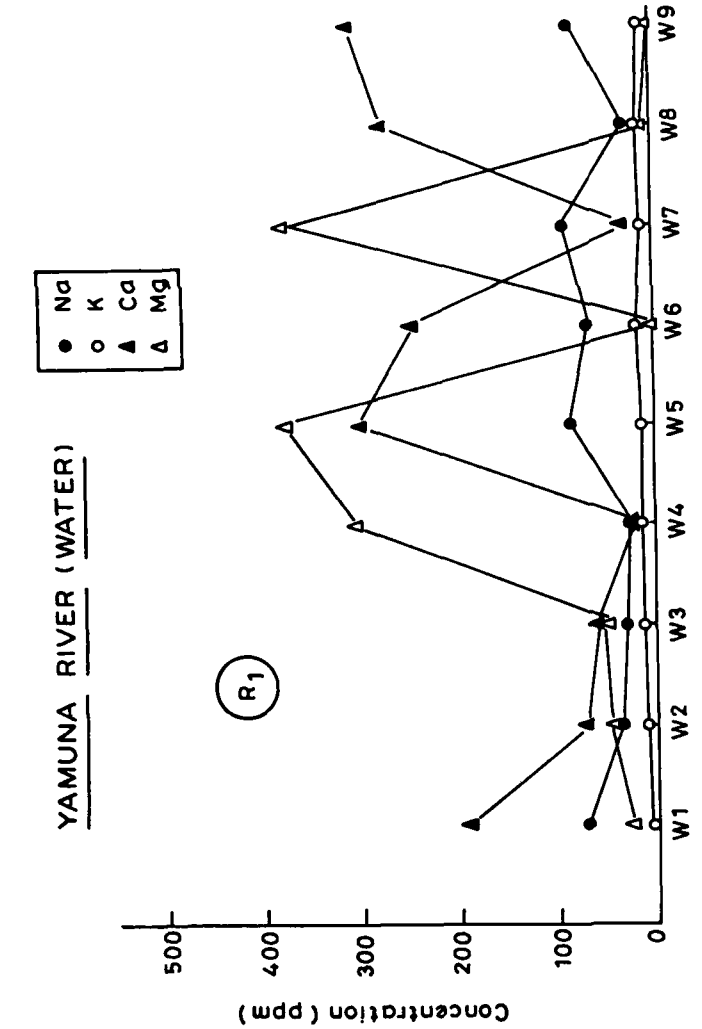


FIG. 1

FIG. 1 - 8 Concentration variation of cations in Yamuna, Hindon, Kali and Ganga river water samples of both sides (R_1 & R_2)

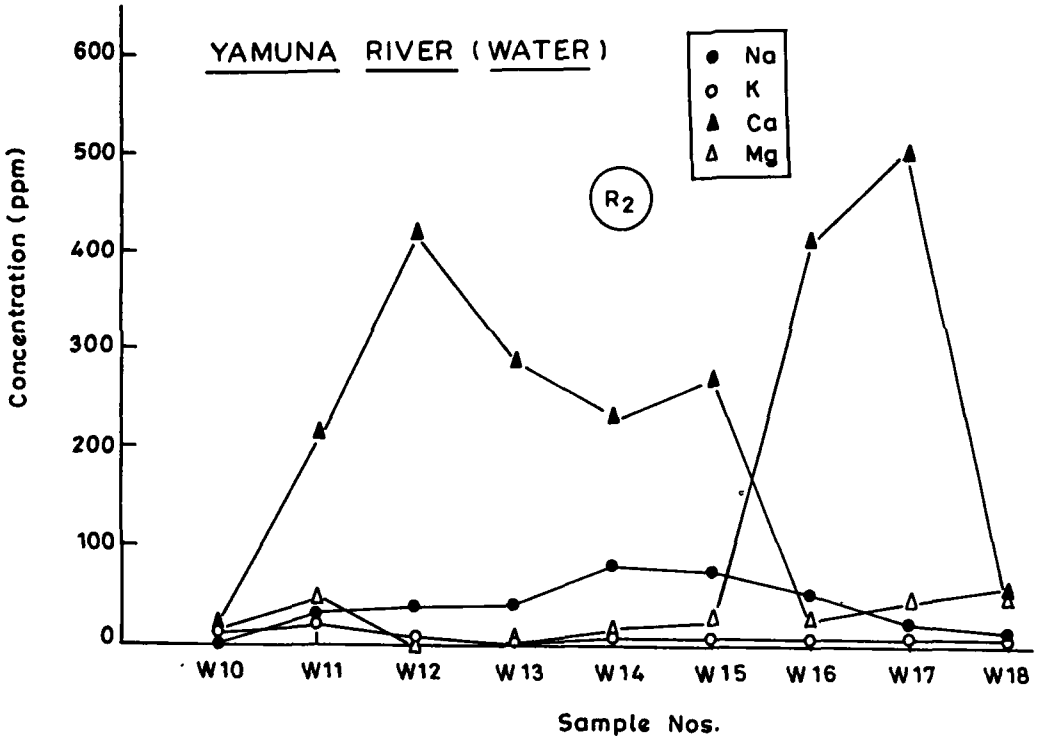


FIG. 2

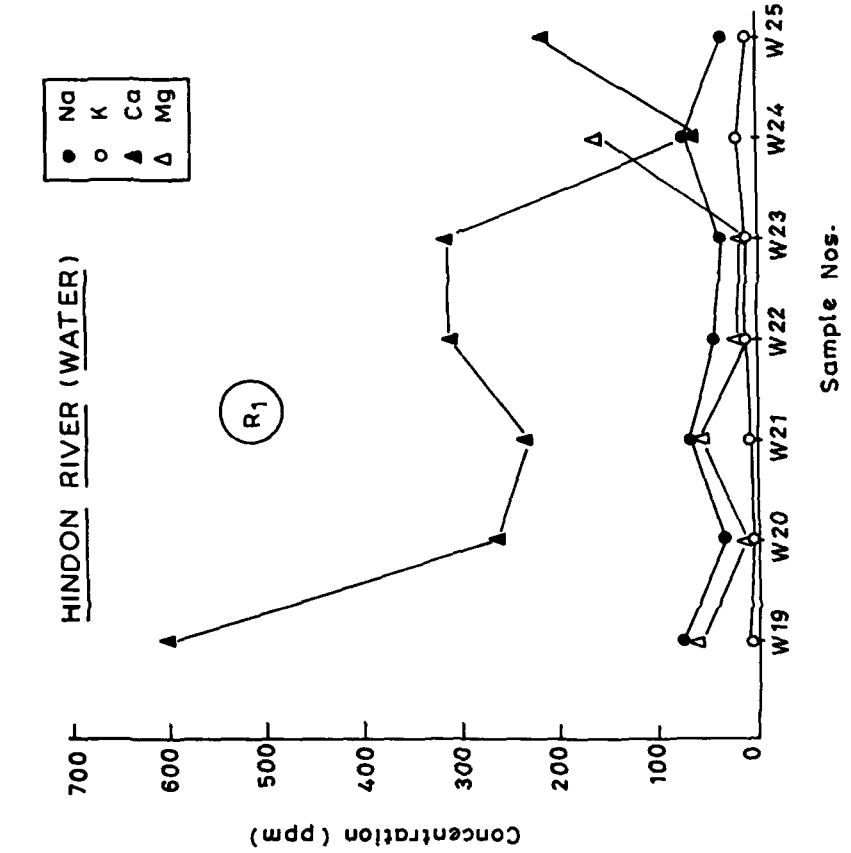

HINDON RIVER (WATER)
R1
Na
K
Ca
Mg
Concentration (ppm)
0
100
200
300
400
500
600
700
W19
W20
W21
W22
W23
W24
W25
Sample Nos.

FIG. 3

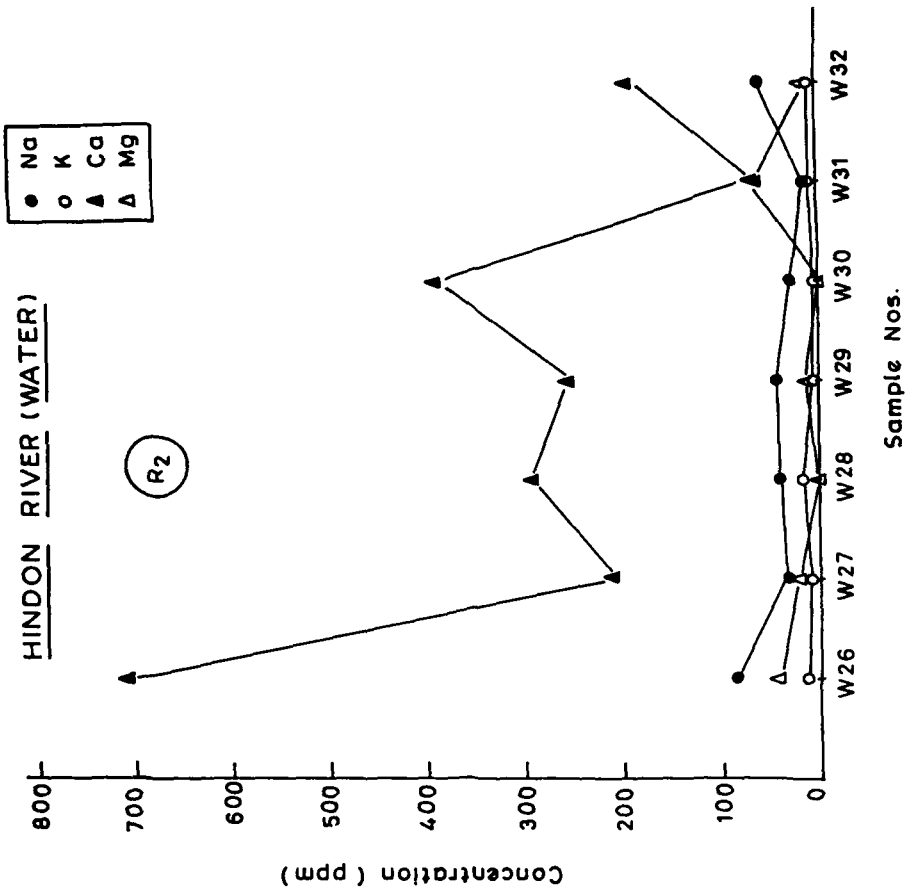

HINDON RIVER (WATER)
R2
Na
K
Ca
Mg
Concentration (ppm)
0
100
200
300
400
500
600
700
800
W26
W27
W28
W29
W30
W31
W32
Sample Nos.

FIG. 4

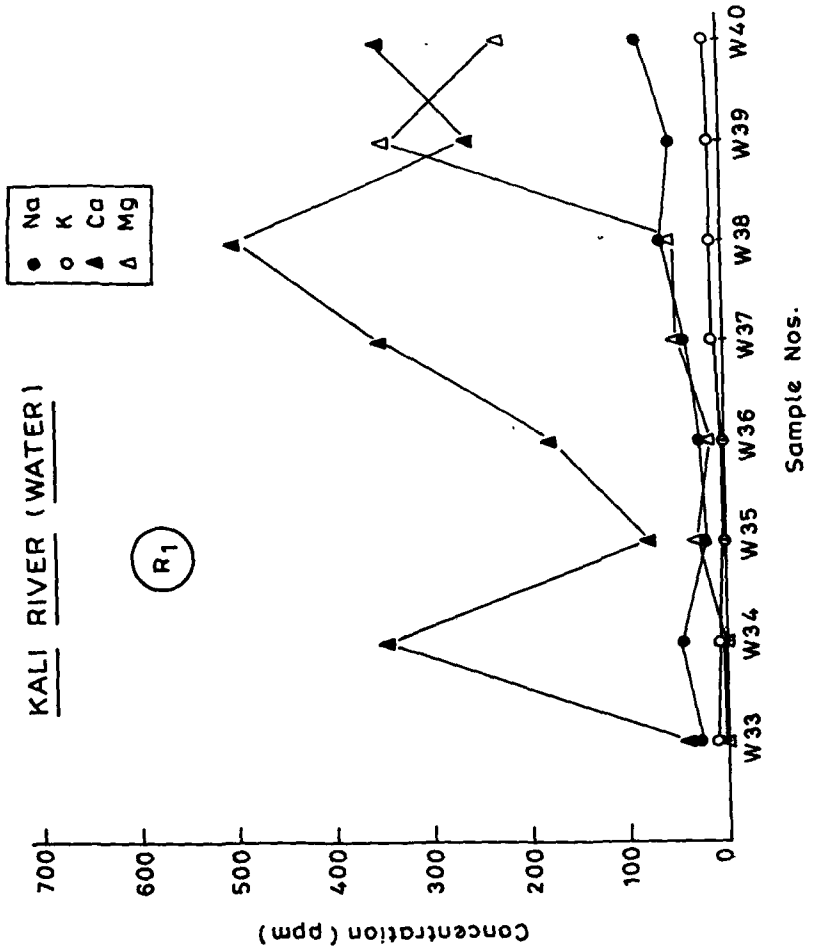

KALI RIVER (WATER)
R1
Na
K
Ca
Mg
Concentration (ppm)
0
100
200
300
400
500
600
700
W33
W34
W35
W36
W37
W38
W39
W40
Sample Nos.

FIG. 5

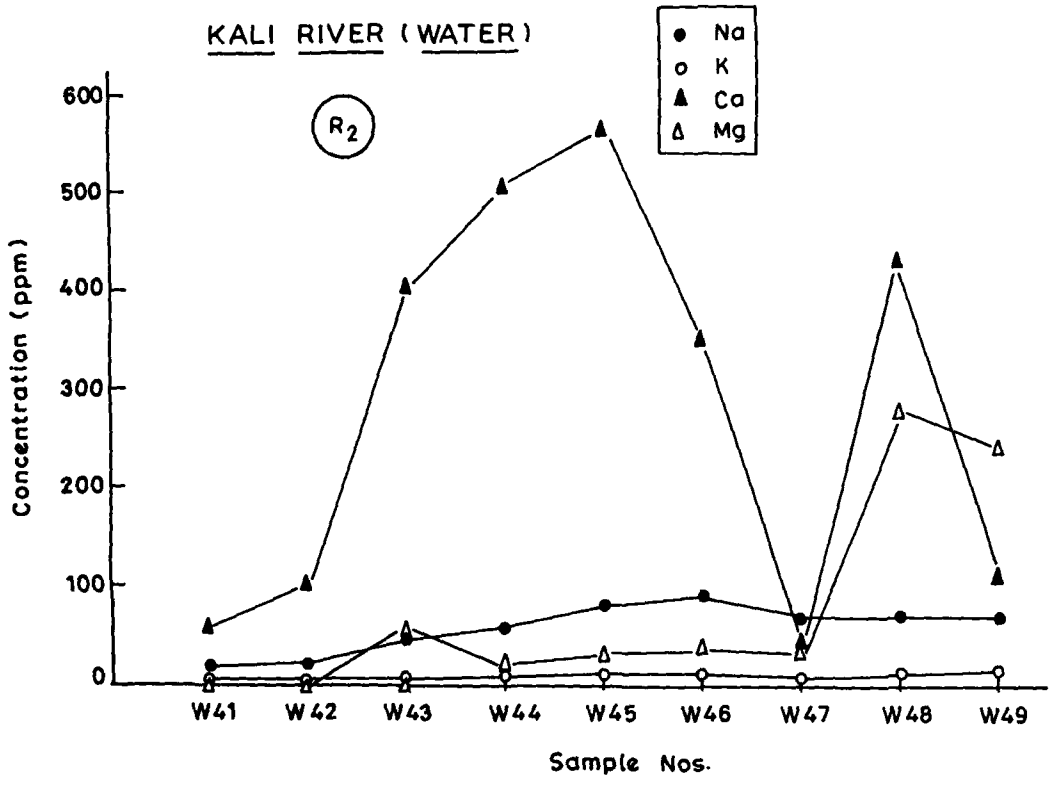

KALI RIVER (WATER)
R2
Na
K
Ca
Mg
Concentration (ppm)
0
100
200
300
400
500
600
W41
W42
W43
W44
W45
W46
W47
W48
W49
Sample Nos.

FIG. 6

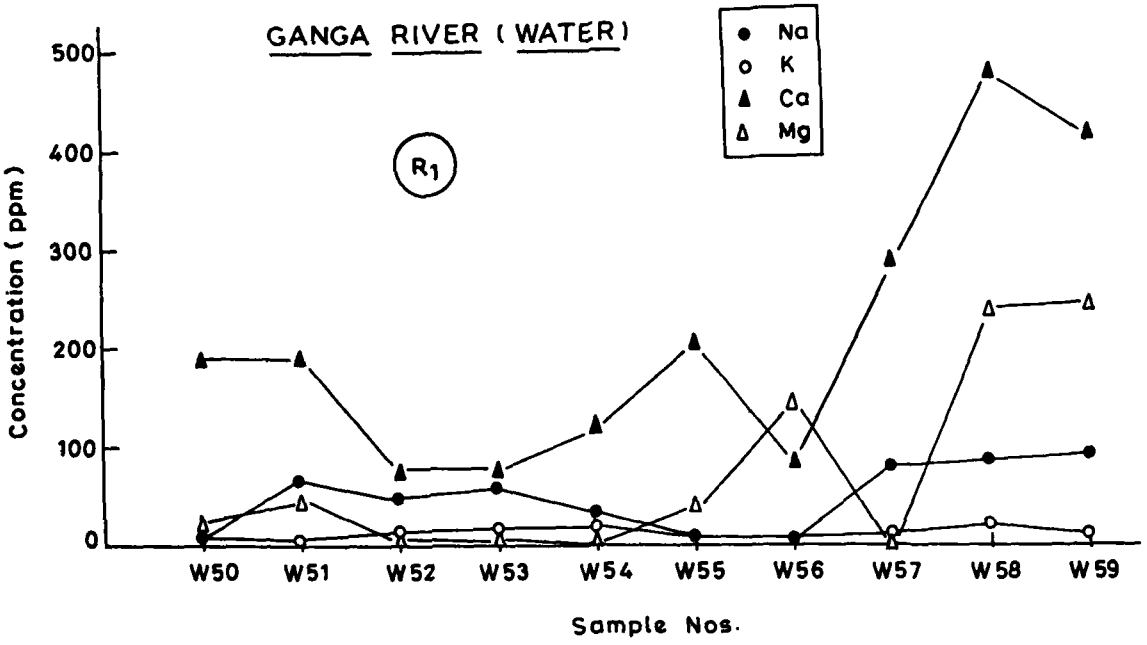

GANGA RIVER (WATER)
Na
K
Ca
Mg
R1
Concentration (ppm)
500
400
300
200
100
0
W50
W51
W52
W53
W54
W55
W56
W57
W58
W59
Sample Nos.

FIG. 7

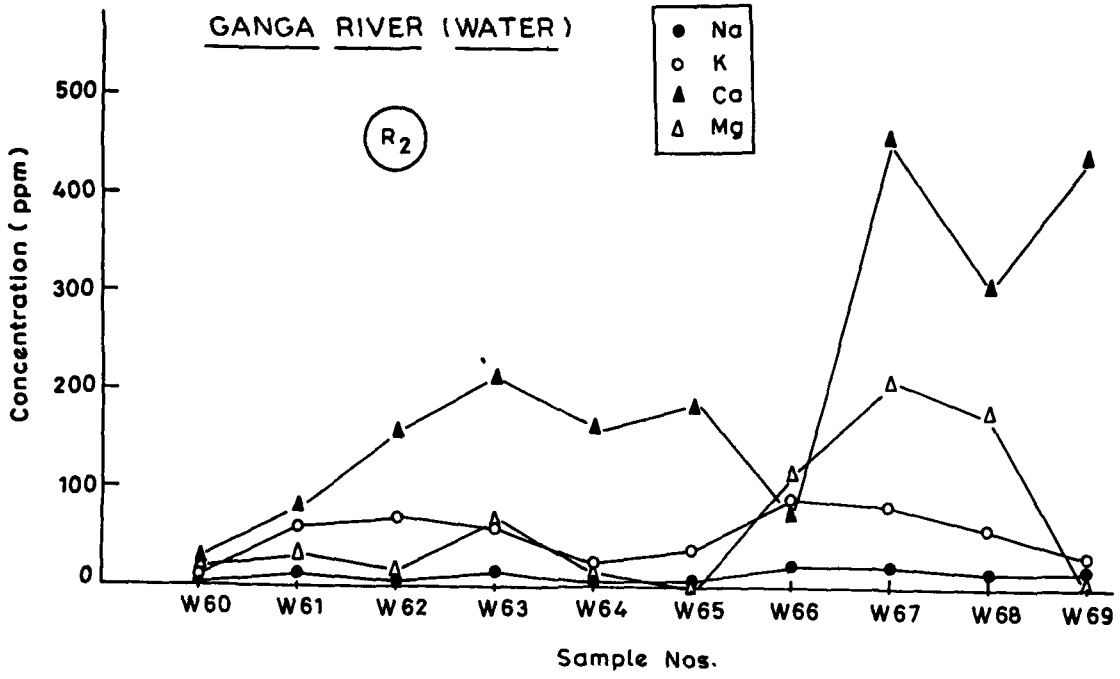

GANGA RIVER (WATER)
Na
K
Ca
Mg
R2
Concentration (ppm)
500
400
300
200
100
0
W60
W61
W62
W63
W64
W65
W66
W67
W68
W69
Sample Nos.

FIG. 8

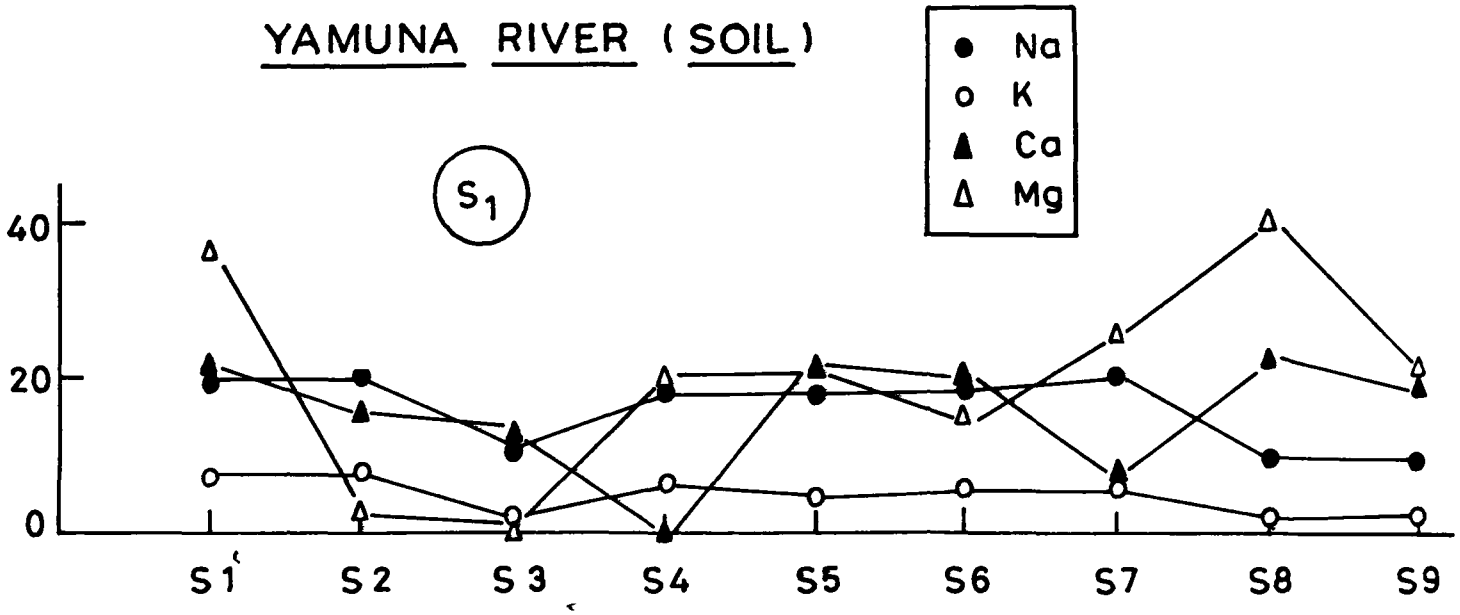


FIG. 9

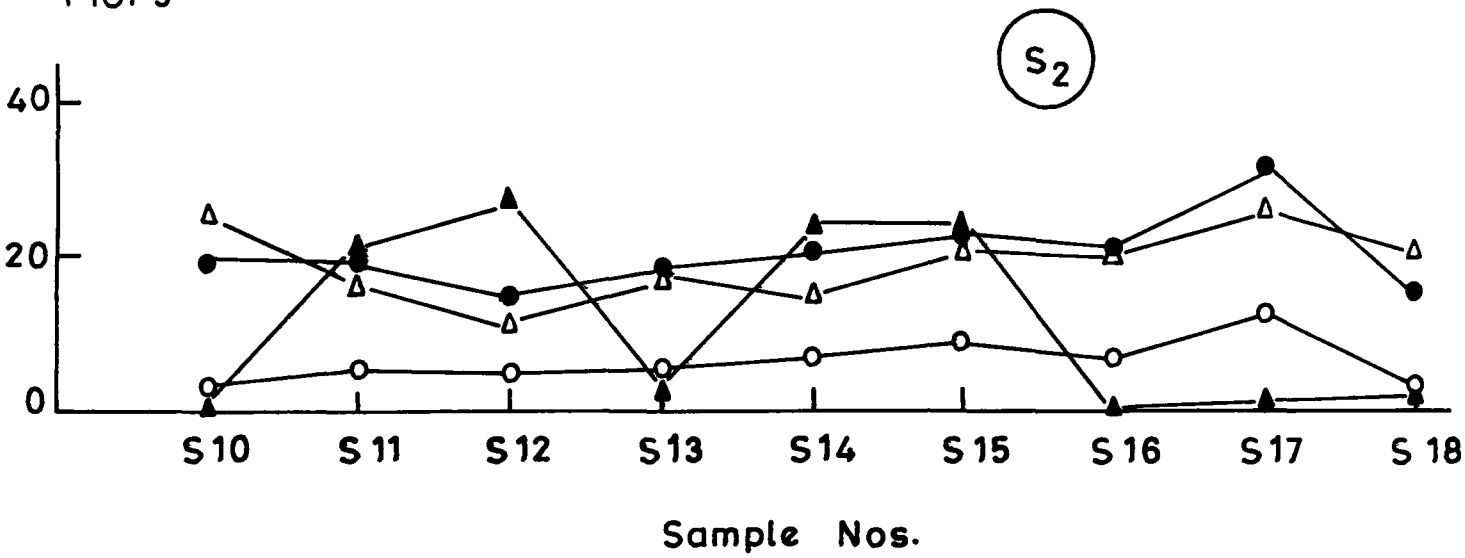


FIG. 10

FIG. 9 – 16 Concentration variation of cations in Yamuna, Hindon, Kali and Ganga river soil samples of both sides (S_1 & S_2)

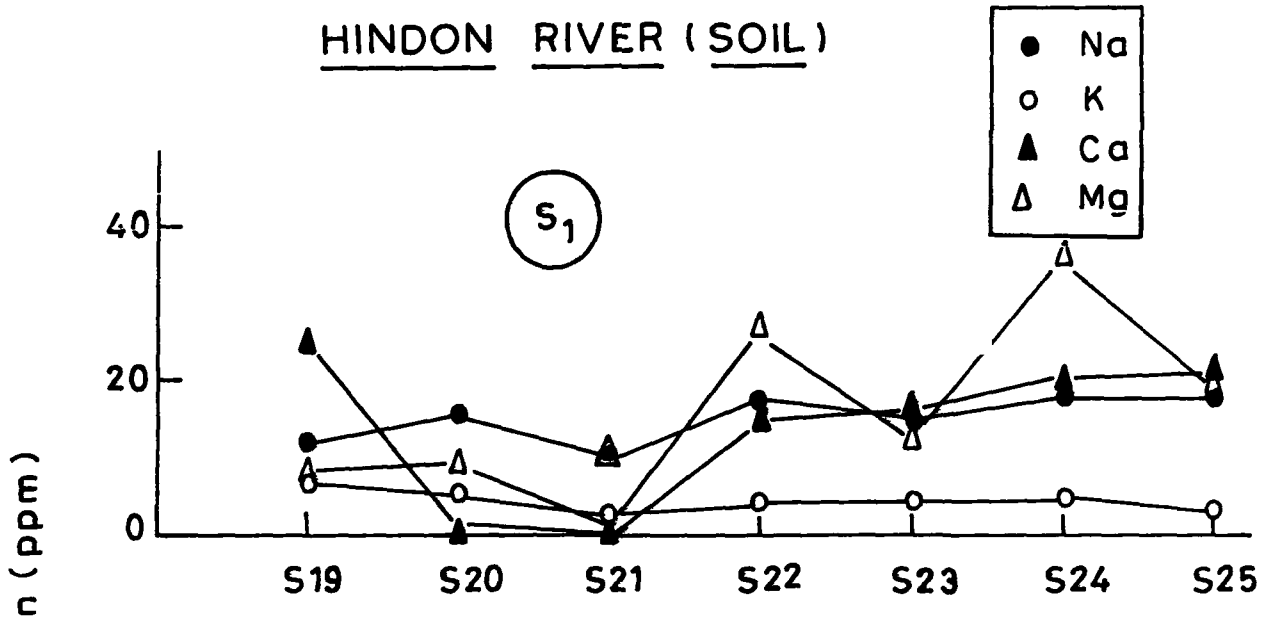

HINDON RIVER (SOIL)
Na
K
Ca
Mg
S1
40
20
0
S19
S20
S21
S22
S23
S24
S25

FIG. 11

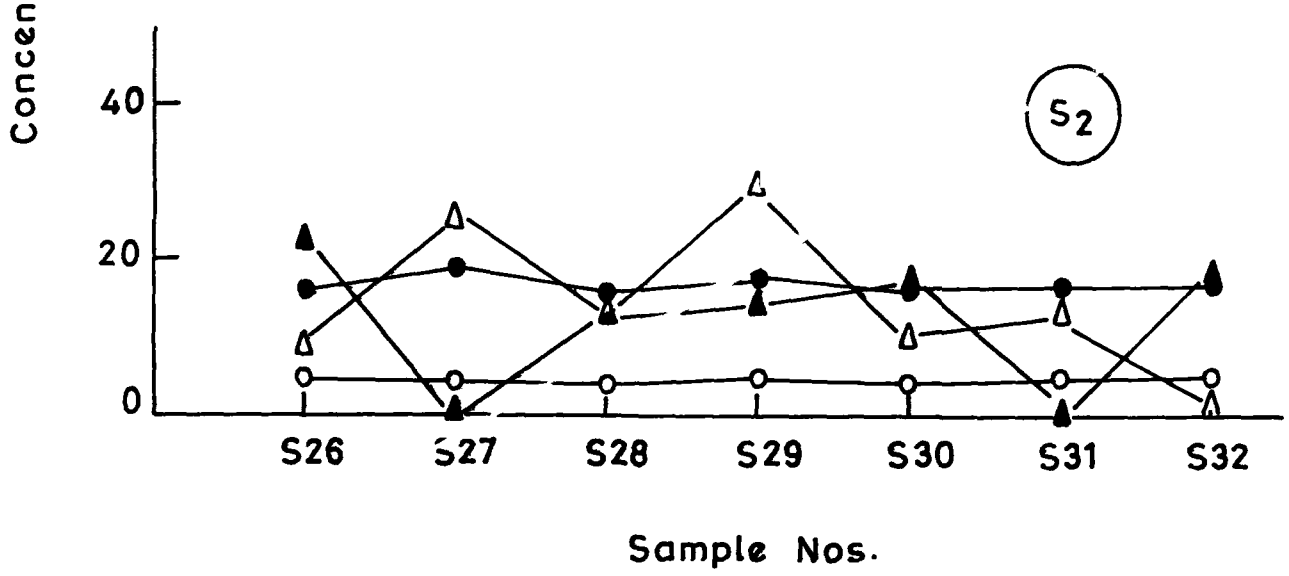

Concentration (ppm)
S2
40
20
0
S26
S27
S28
S29
S30
S31
S32
Sample Nos.

FIG. 12

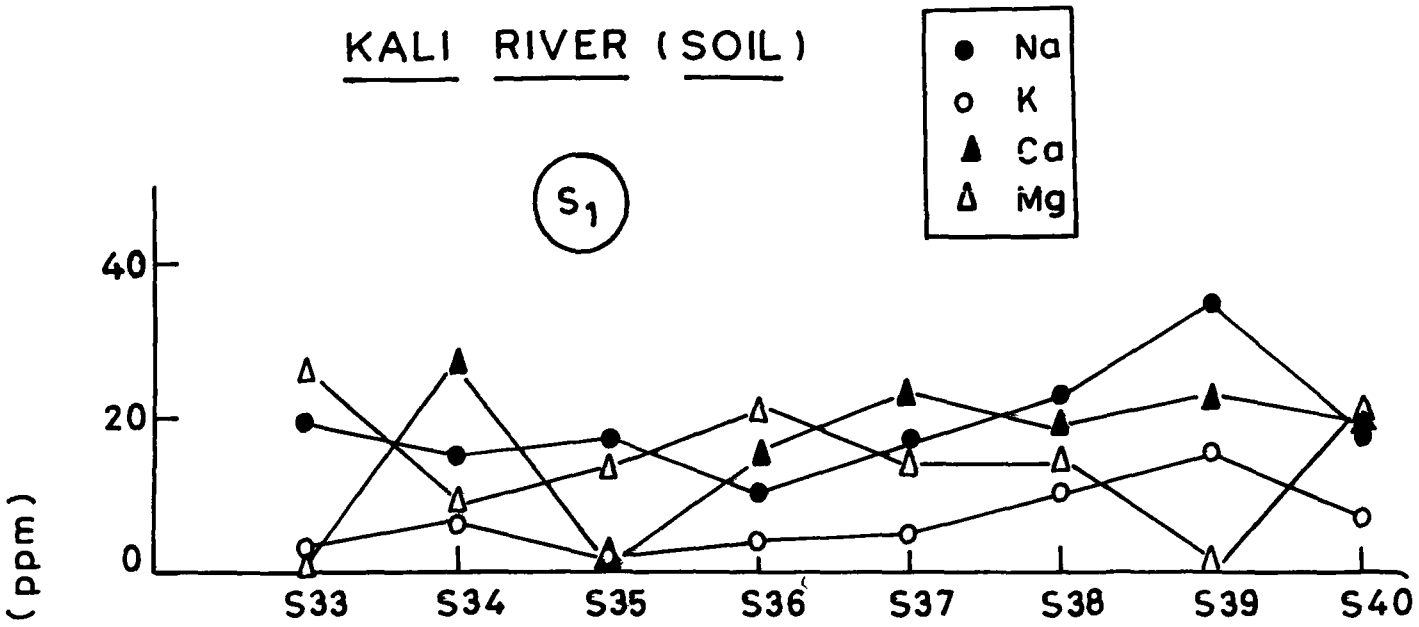

KALI RIVER (SOIL)
Na
K
Ca
Mg
S1
40
20
0
S33
S34
S35
S36
S37
S38
S39
S40

FIG. 13

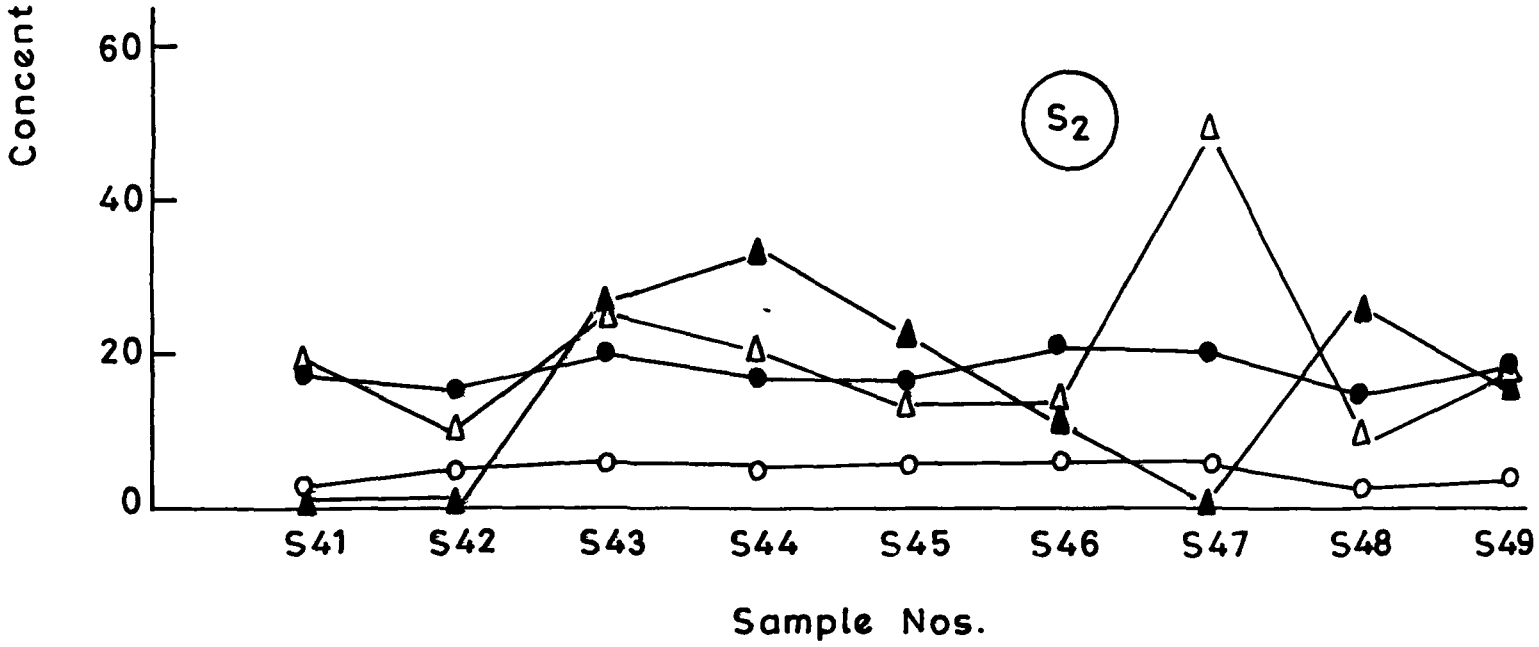

Concentration (ppm)
60
40
20
0
S2
S41
S42
S43
S44
S45
S46
S47
S48
S49
Sample Nos.

FIG. 14

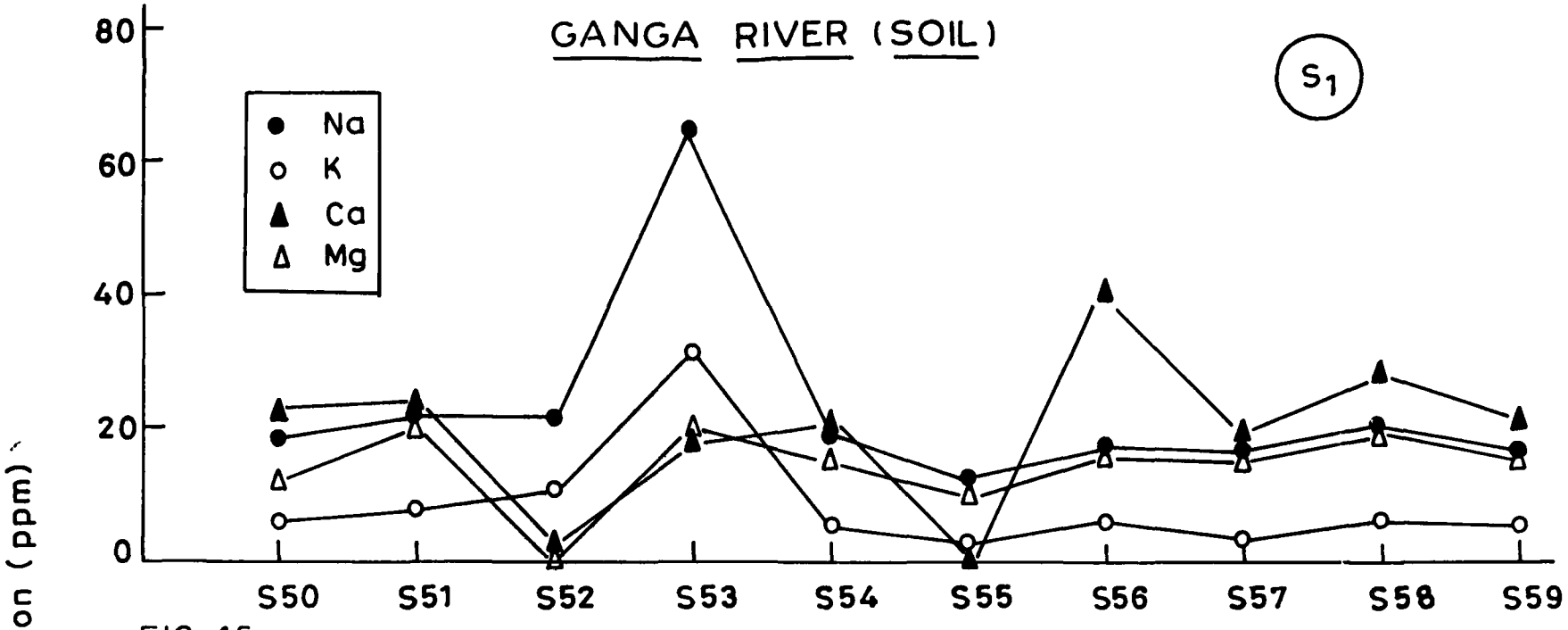

GANGA RIVER (SOIL)
S1
Na
K
Ca
Mg
80
60
40
20
0
S50
S51
S52
S53
S54
S55
S56
S57
S58
S59

FIG. 15

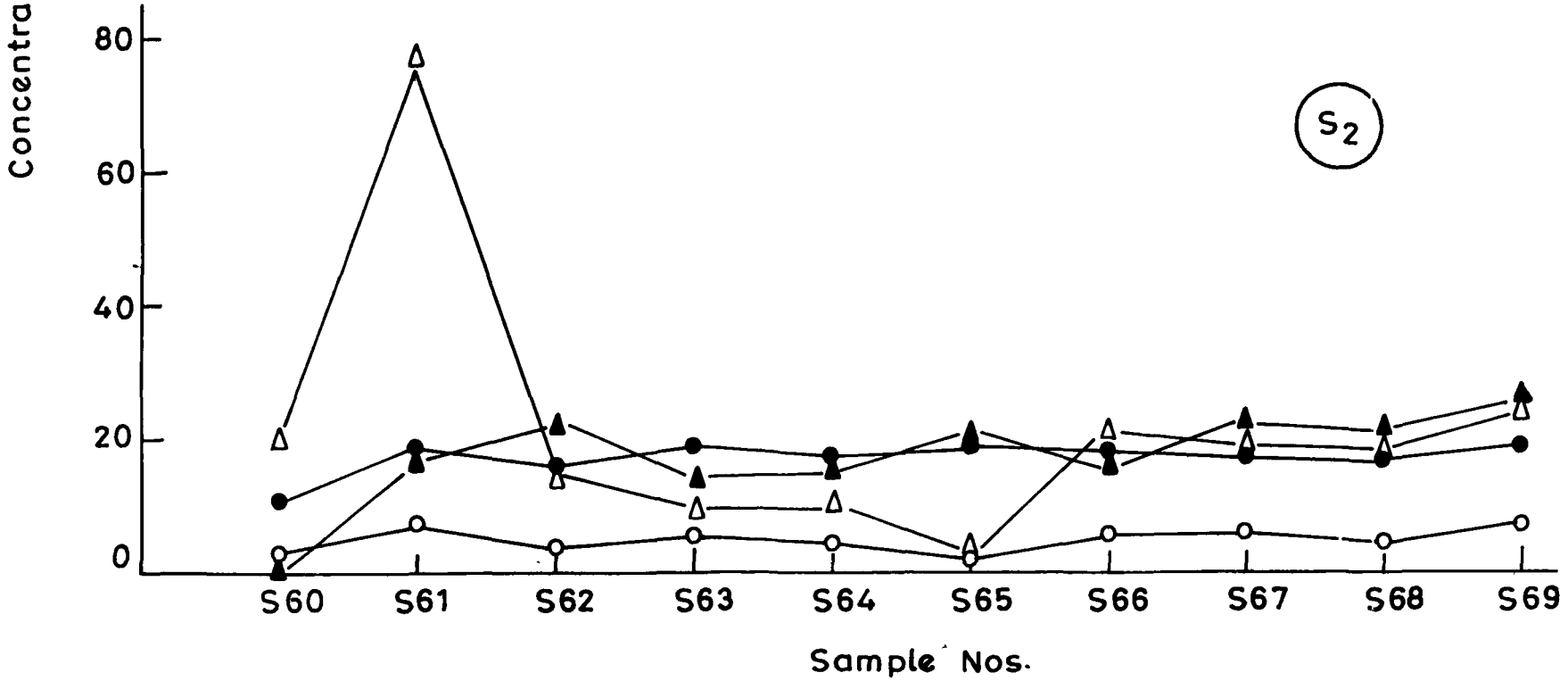

S2
80
60
40
20
0
S60
S61
S62
S63
S64
S65
S66
S67
S68
S69
Concentration (ppm)
Sample Nos.

FIG. 16

YAMUNA RIVER

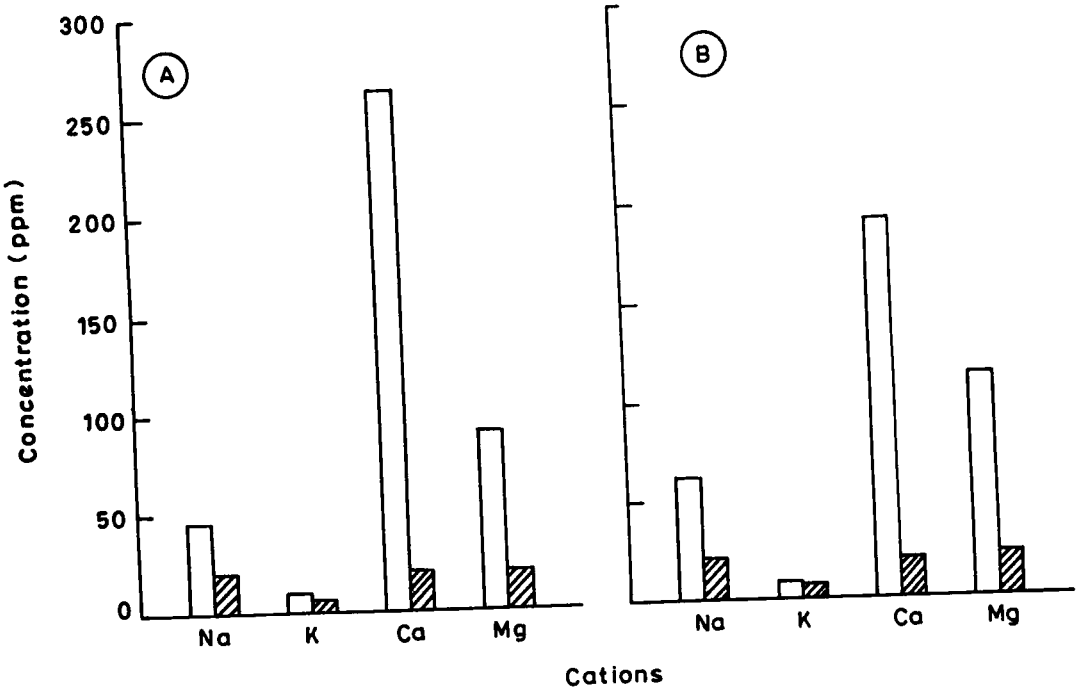


FIG. 17

FIG. 17 - 20 Showing average concentration of cations in Yamuna, Hindon, Kali and Ganga river water and soil of both sides (A and B)

HINDON RIVER

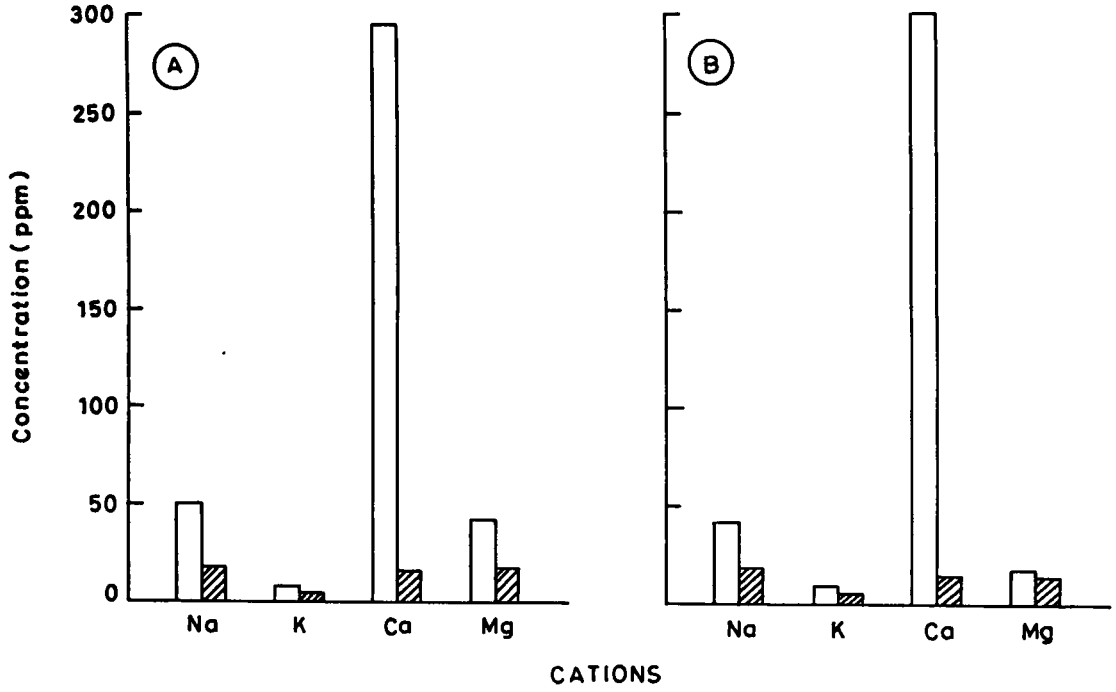


FIG. 18

KALI RIVER

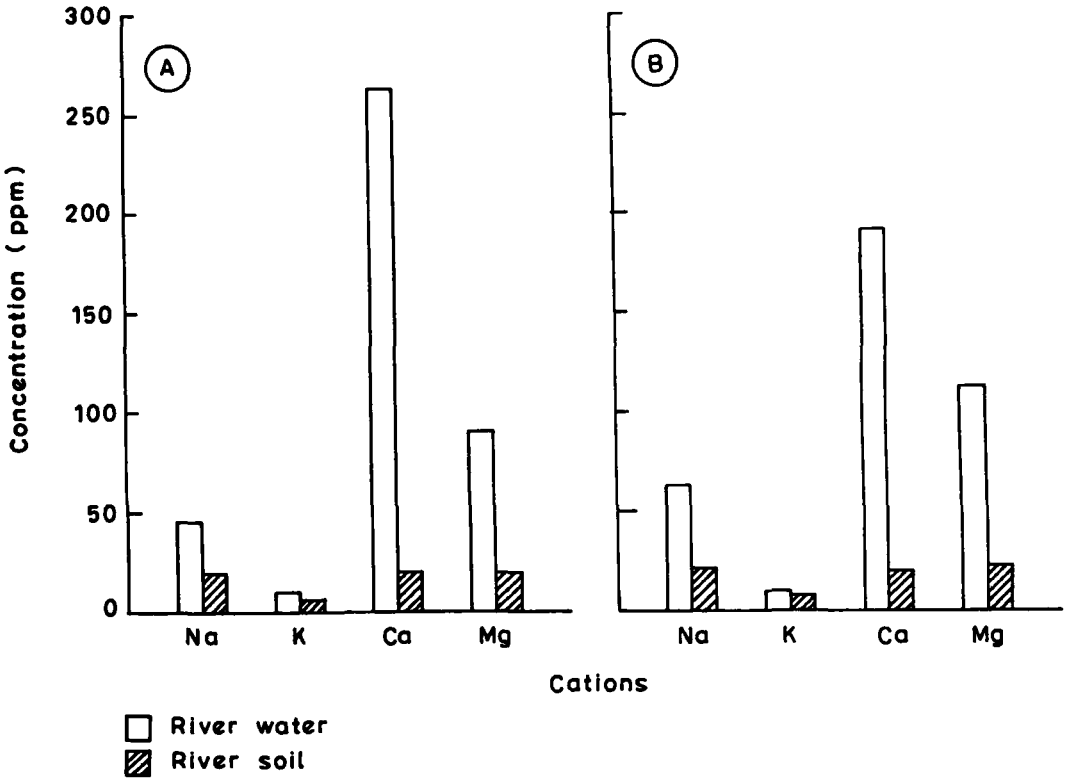


FIG. 19

GANGA RIVER

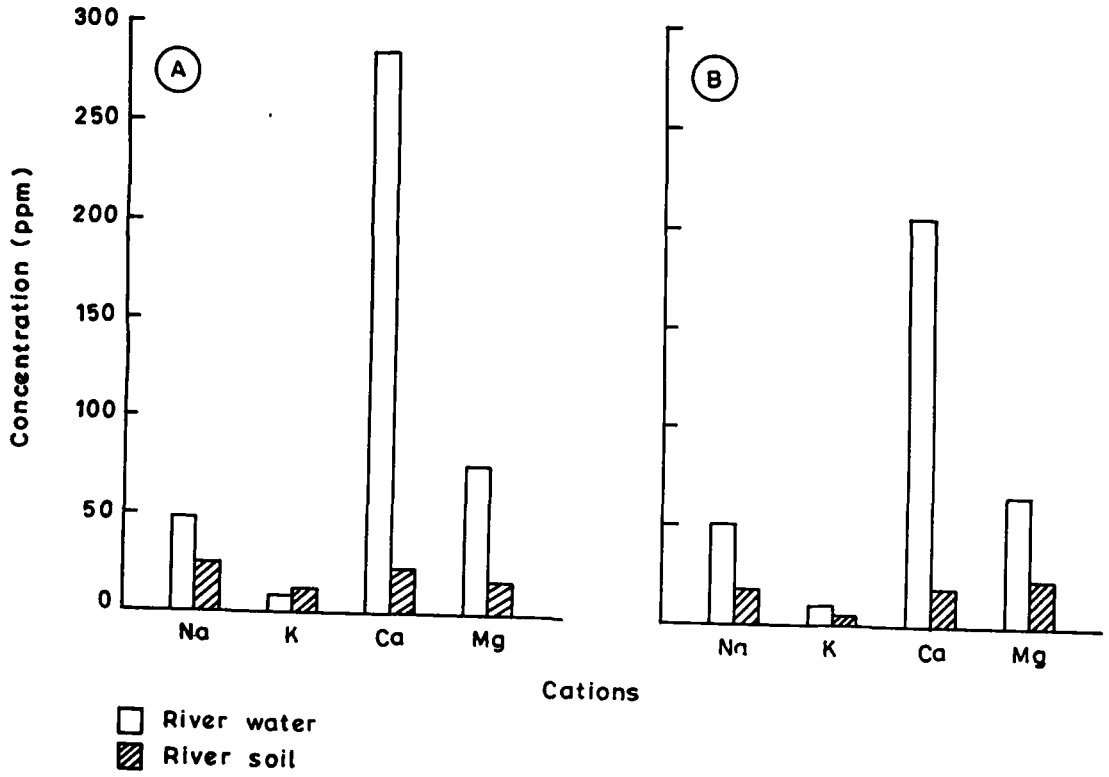


FIG. 20

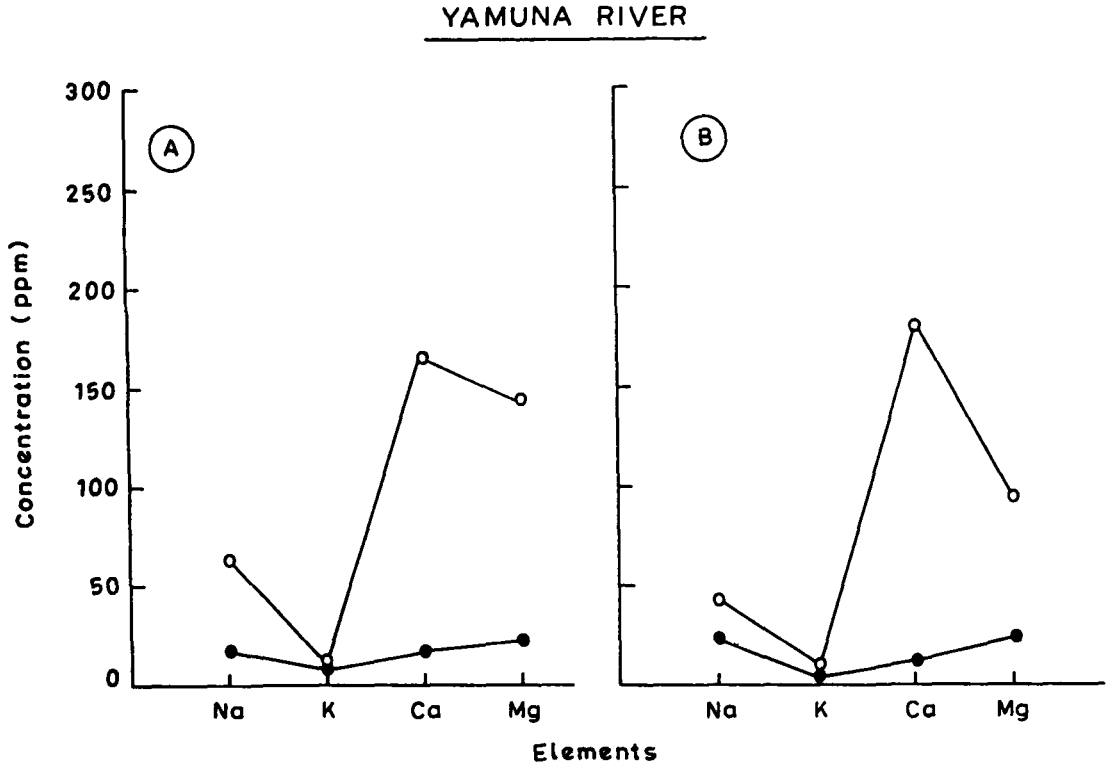


FIG. 21

FIG. 21-24 Showing relationship of average concentration of cations in Yamuna, Hindon, Kali and Ganga river water and soil of both sides (A and B)

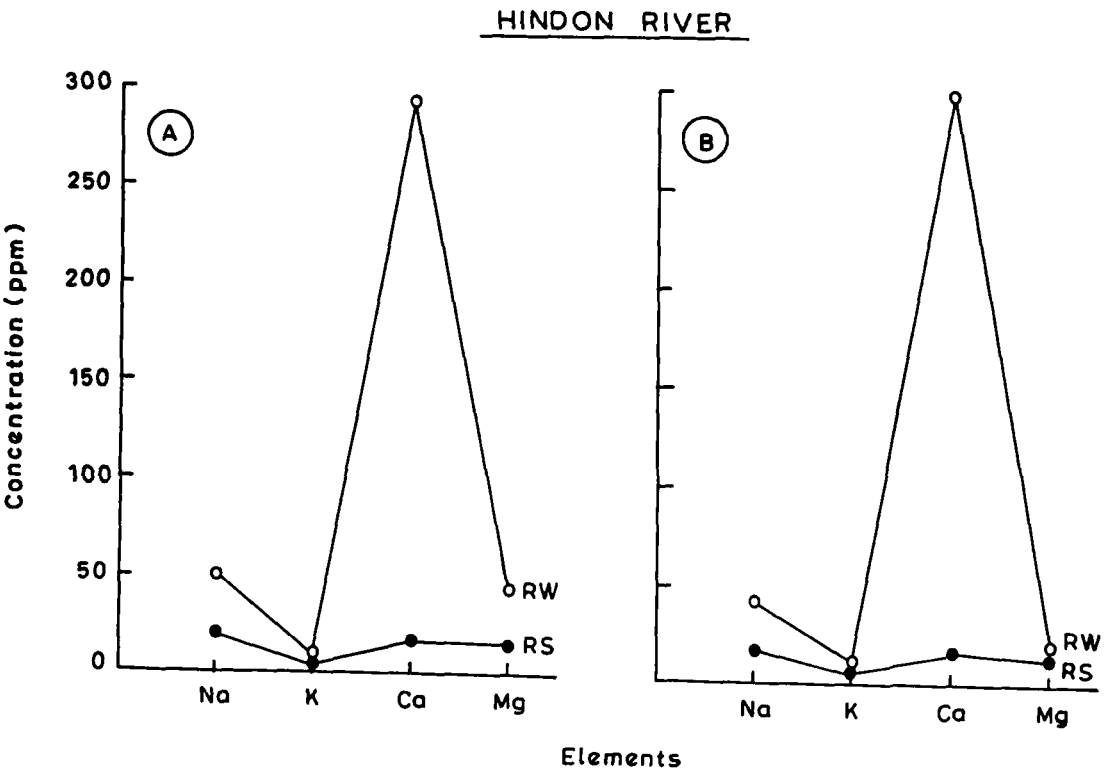


FIG. 22

KALI RIVER

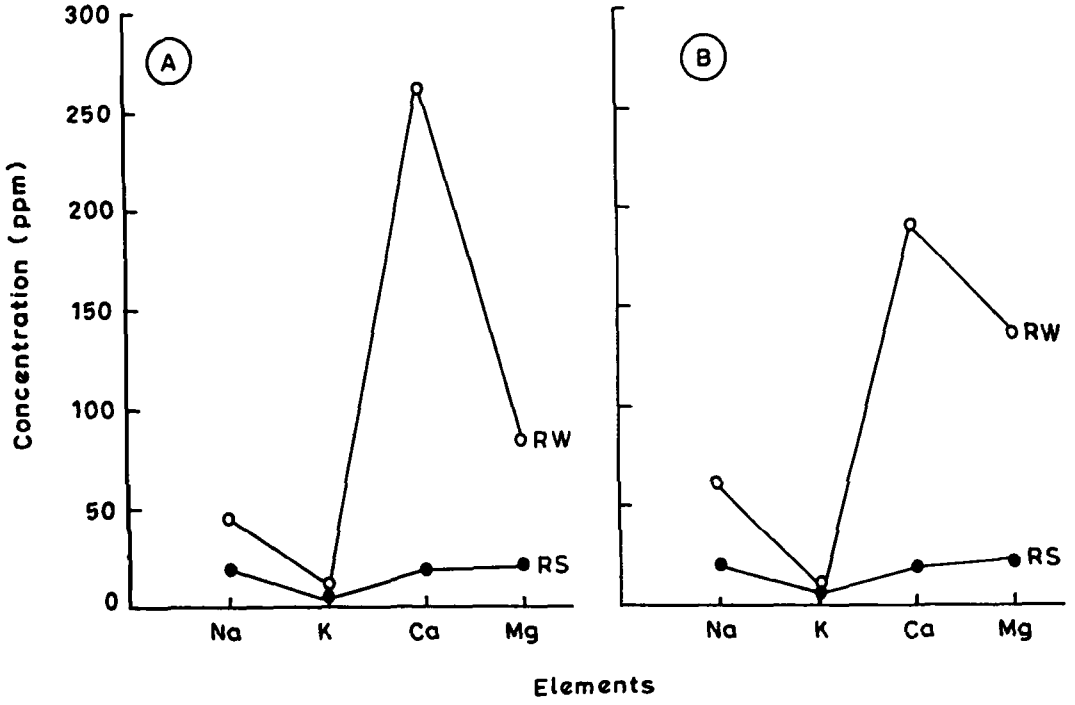


FIG. 23

GANGA RIVER

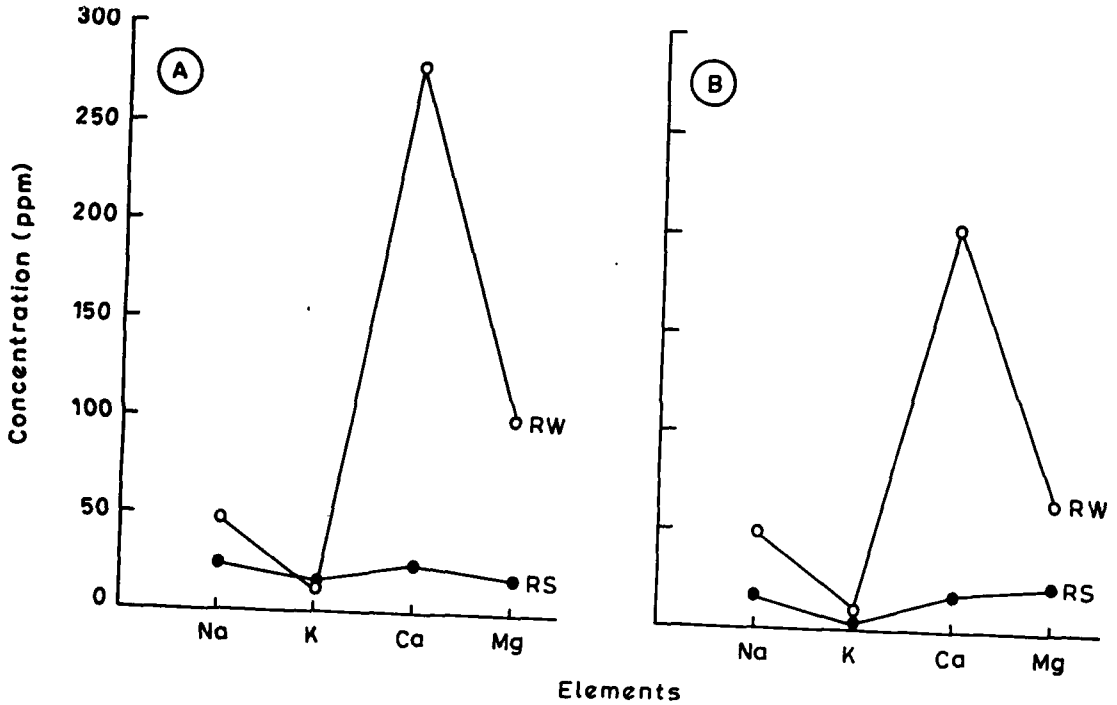


FIG. 24

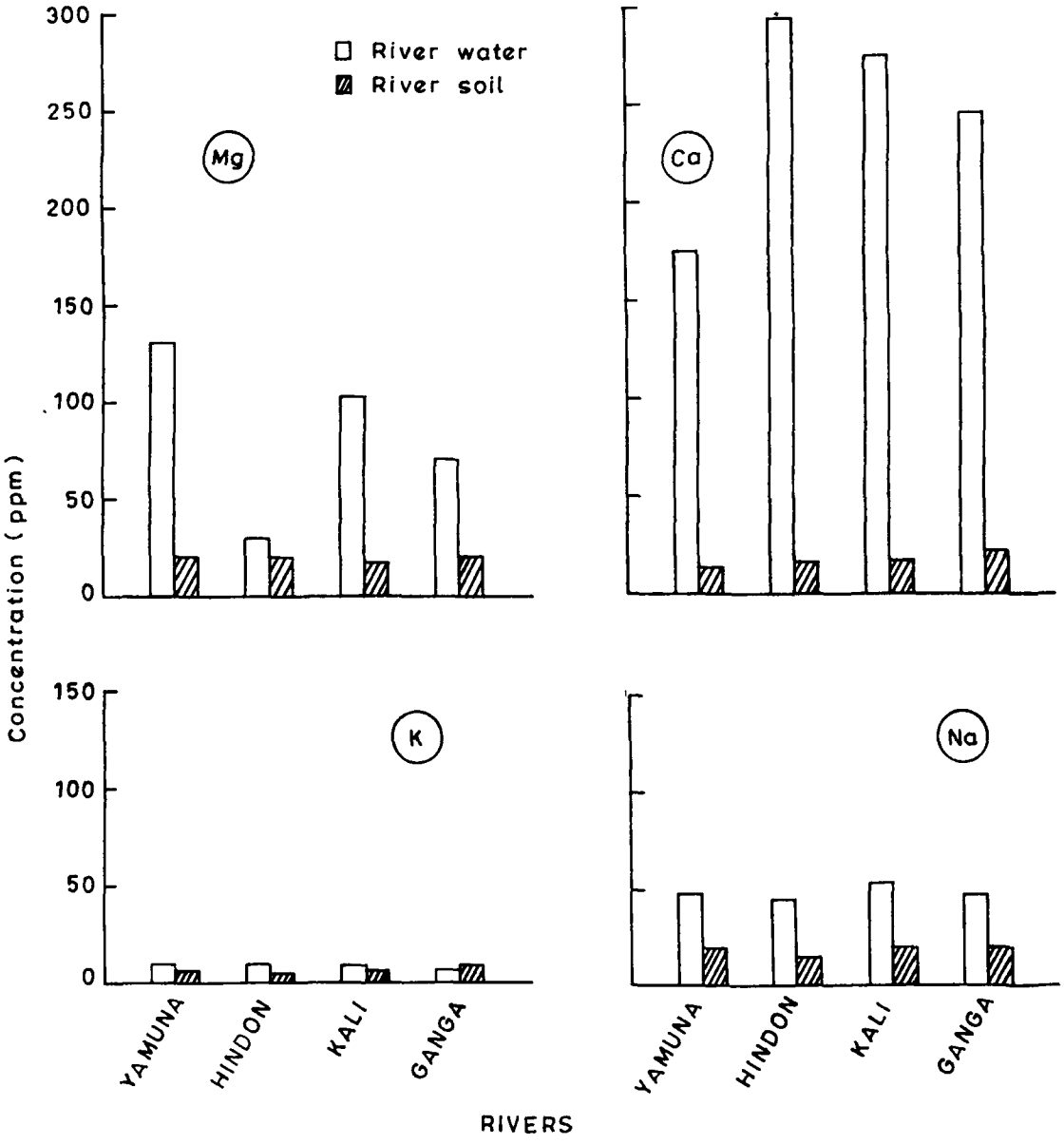


FIG. 25 Showing total average concentration of cations in Yamuna, Hindon, Kali and Ganga river water and soil.

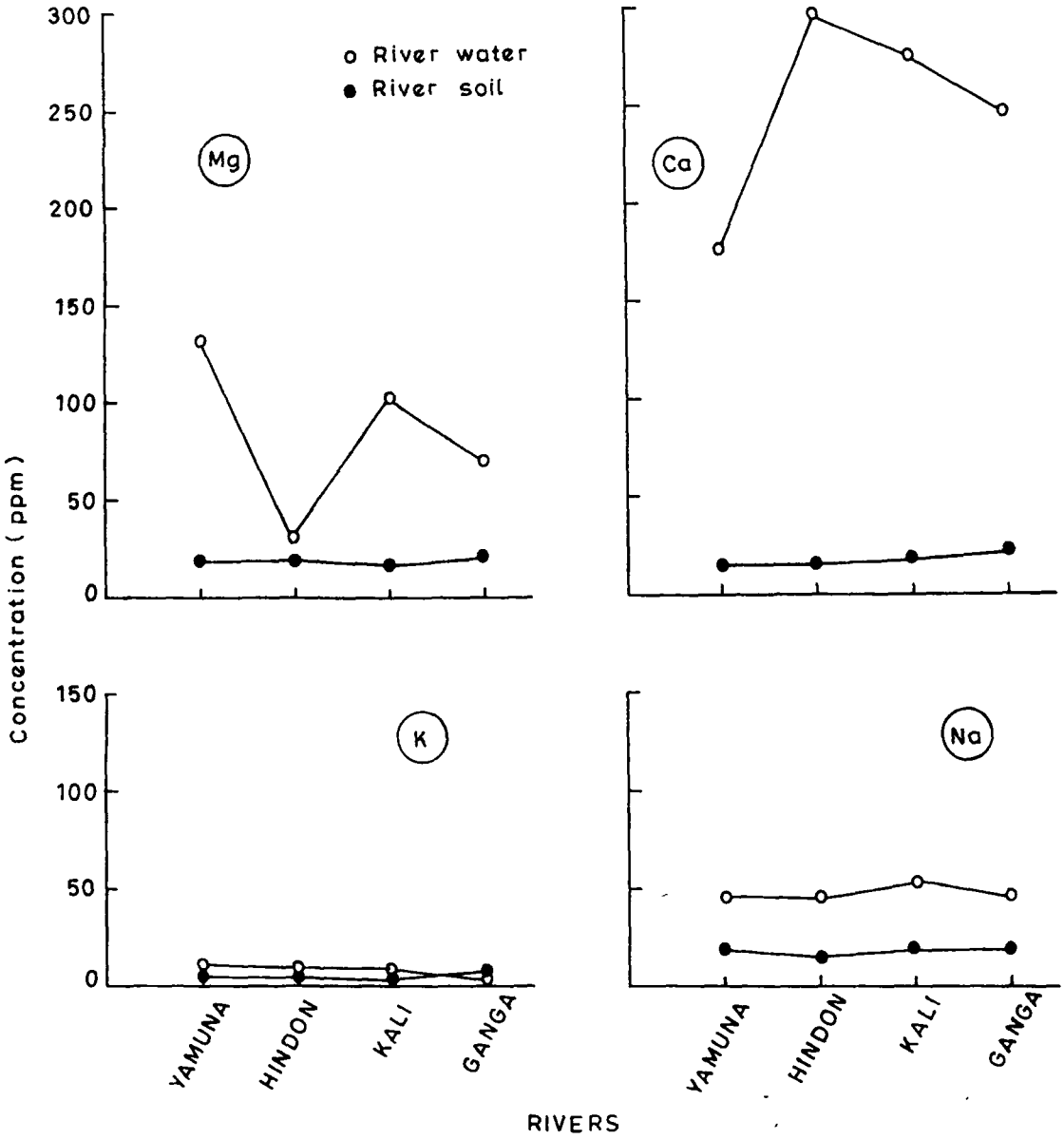


FIG. 26 Showing relationship of total average concentration of cations in Yamuna, Hindon, Kali and Ganga river water and soil

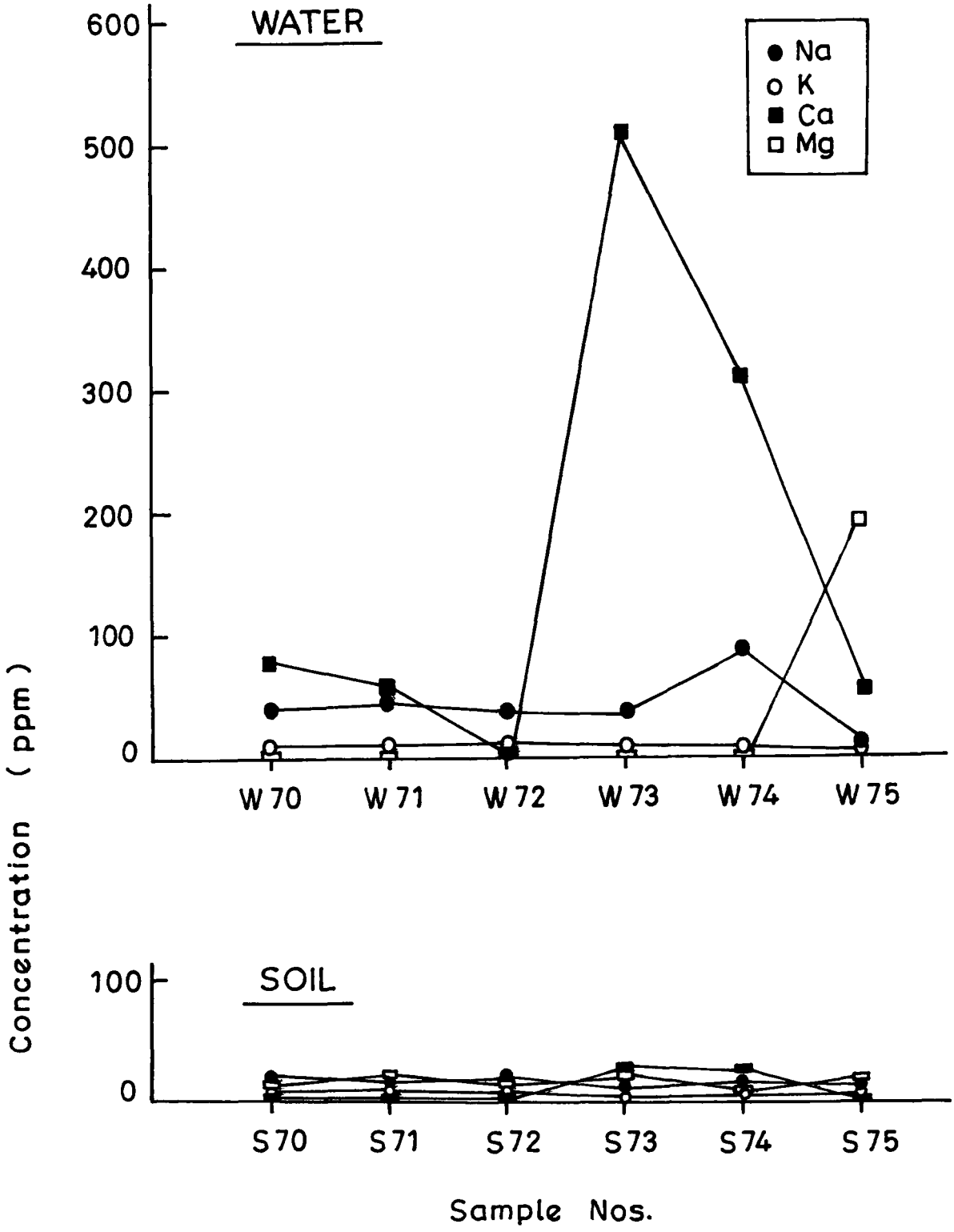


FIG. 27 Concentration variation of cations in groundwater and soil samples

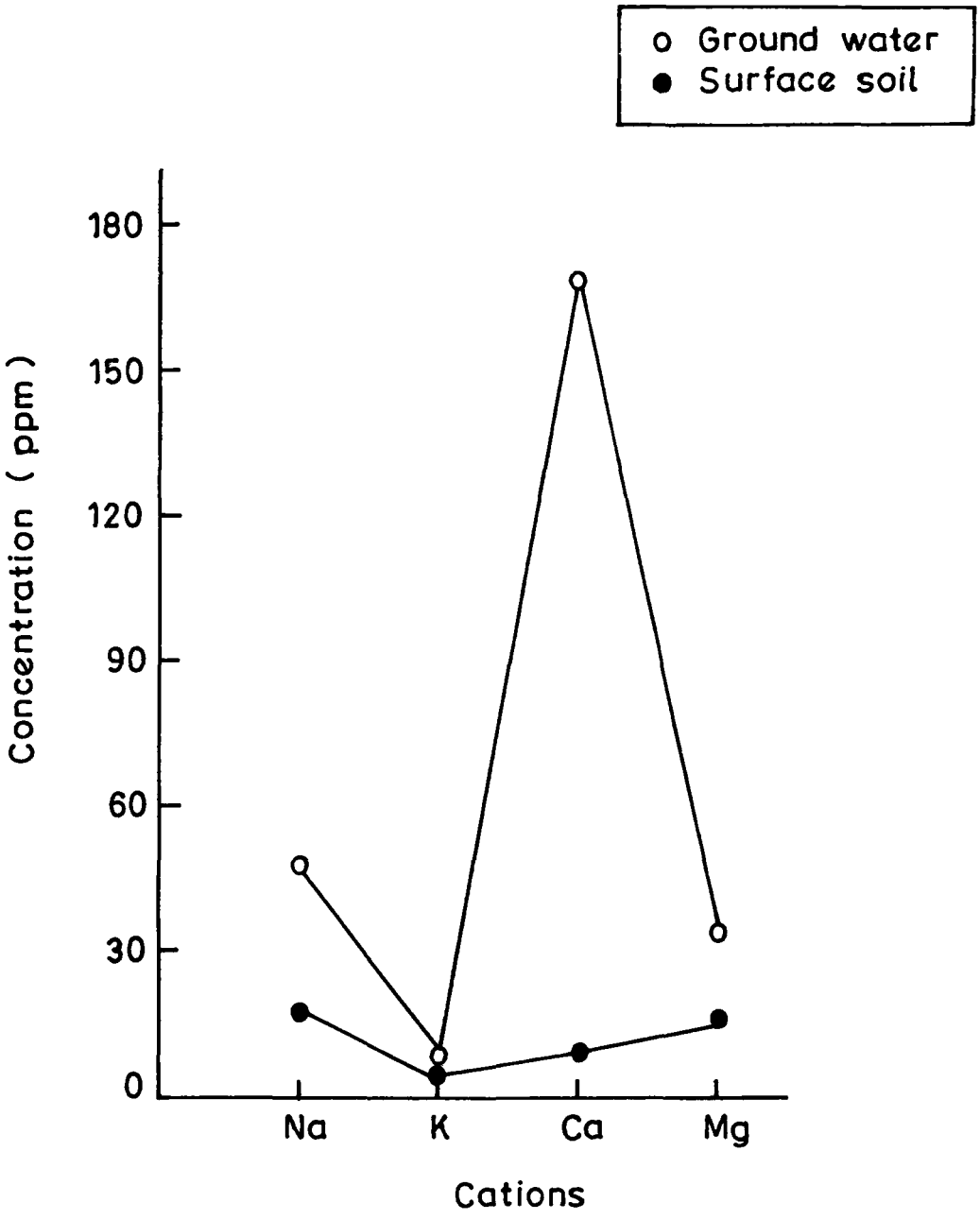


FIG. 28 Showing relationship of average concentration of cations in groundwater and soil samples

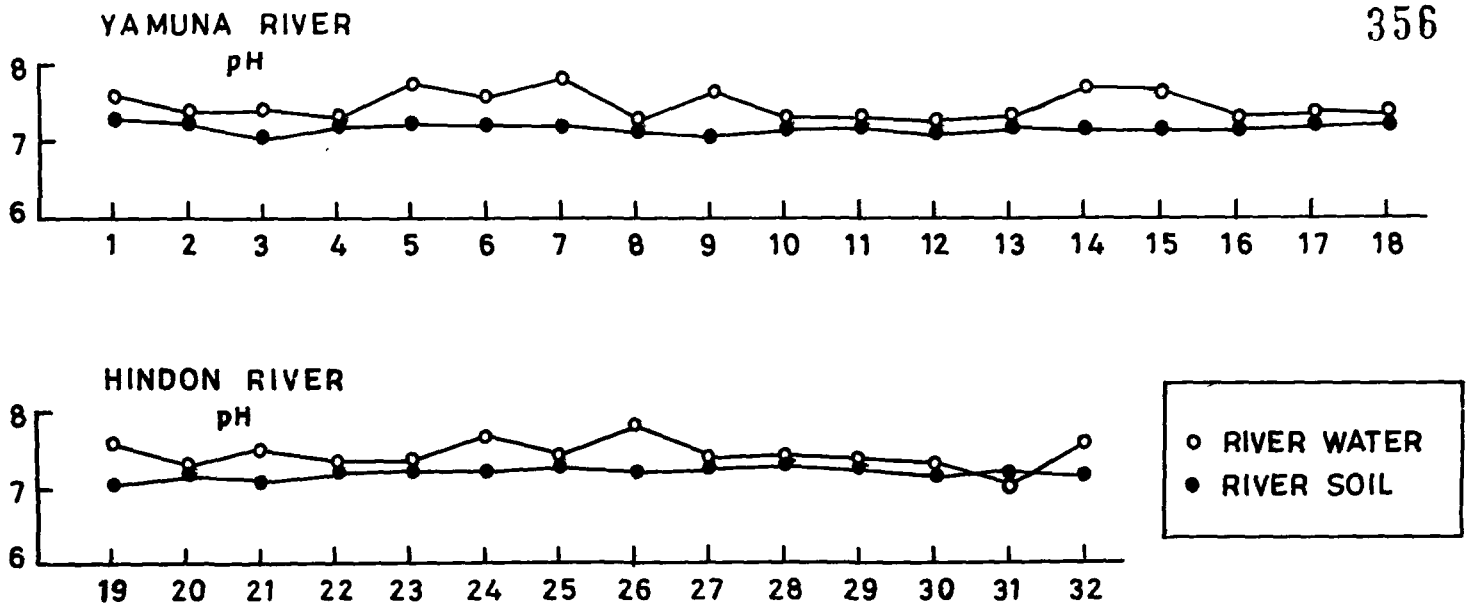


FIG. 29

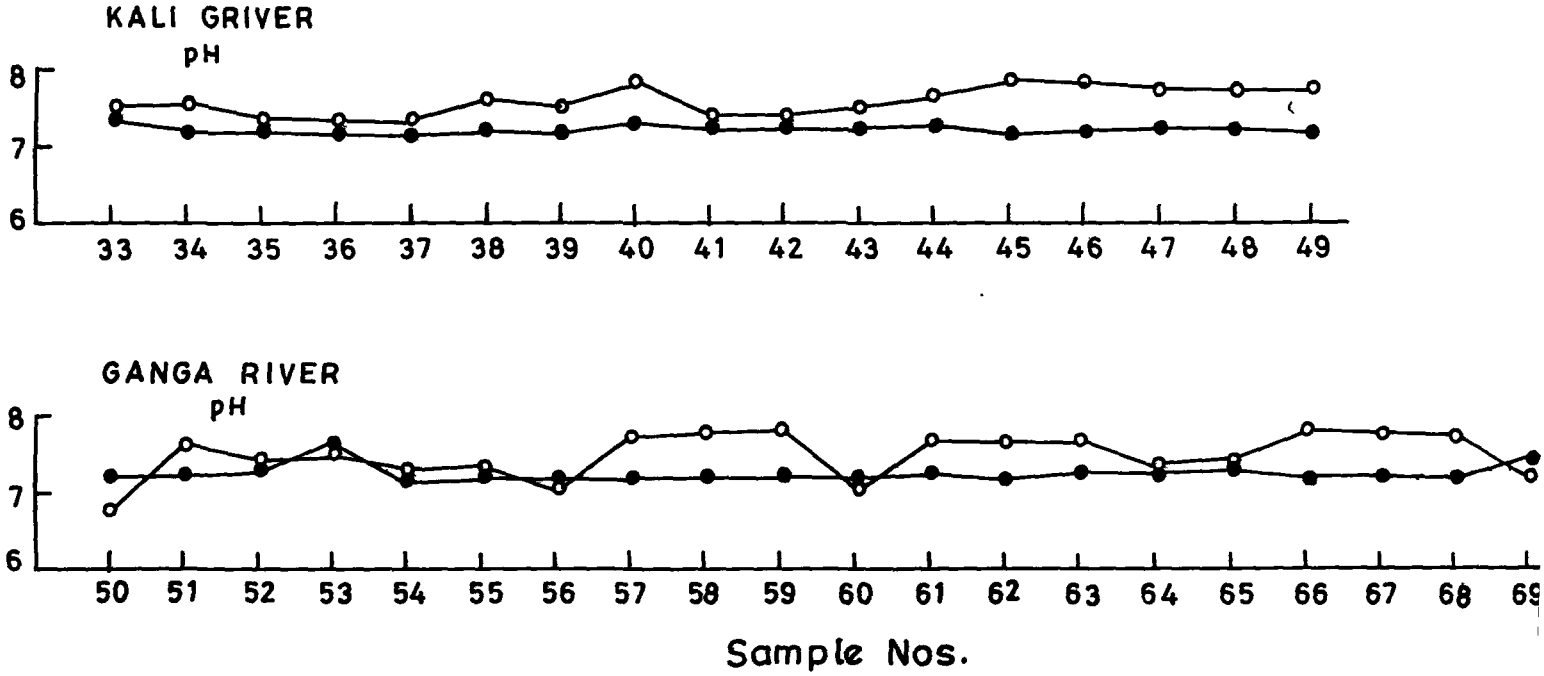


FIG. 30

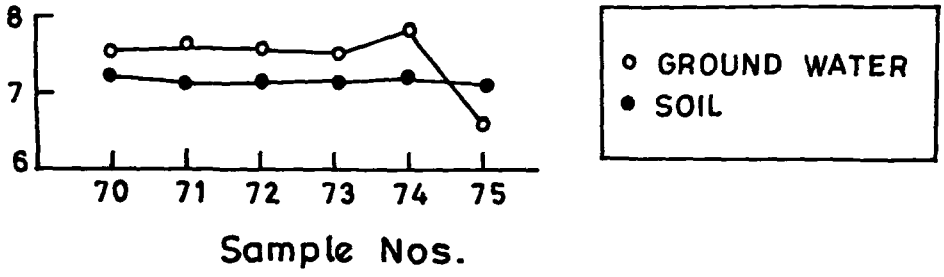


FIG. 31

FIG. 29 – 31 Showing relationship of pH in river water, ground water and associated soil samples

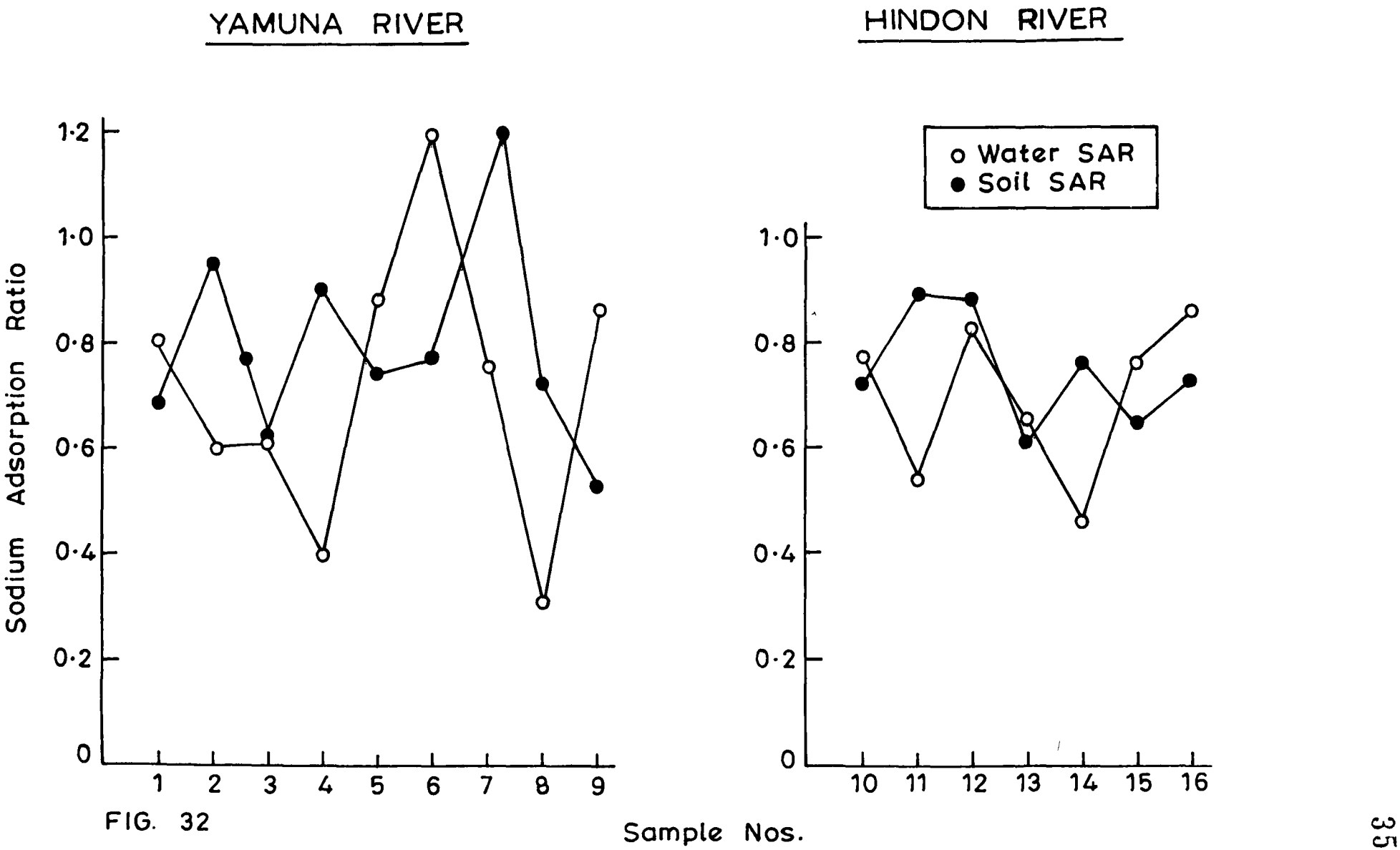


FIG. 32

FIG. 32 & 33 Showing relationship of Sodium Adsorption Ratio in Yamuna, Hindon, Kali and Ganga river water and soil samples

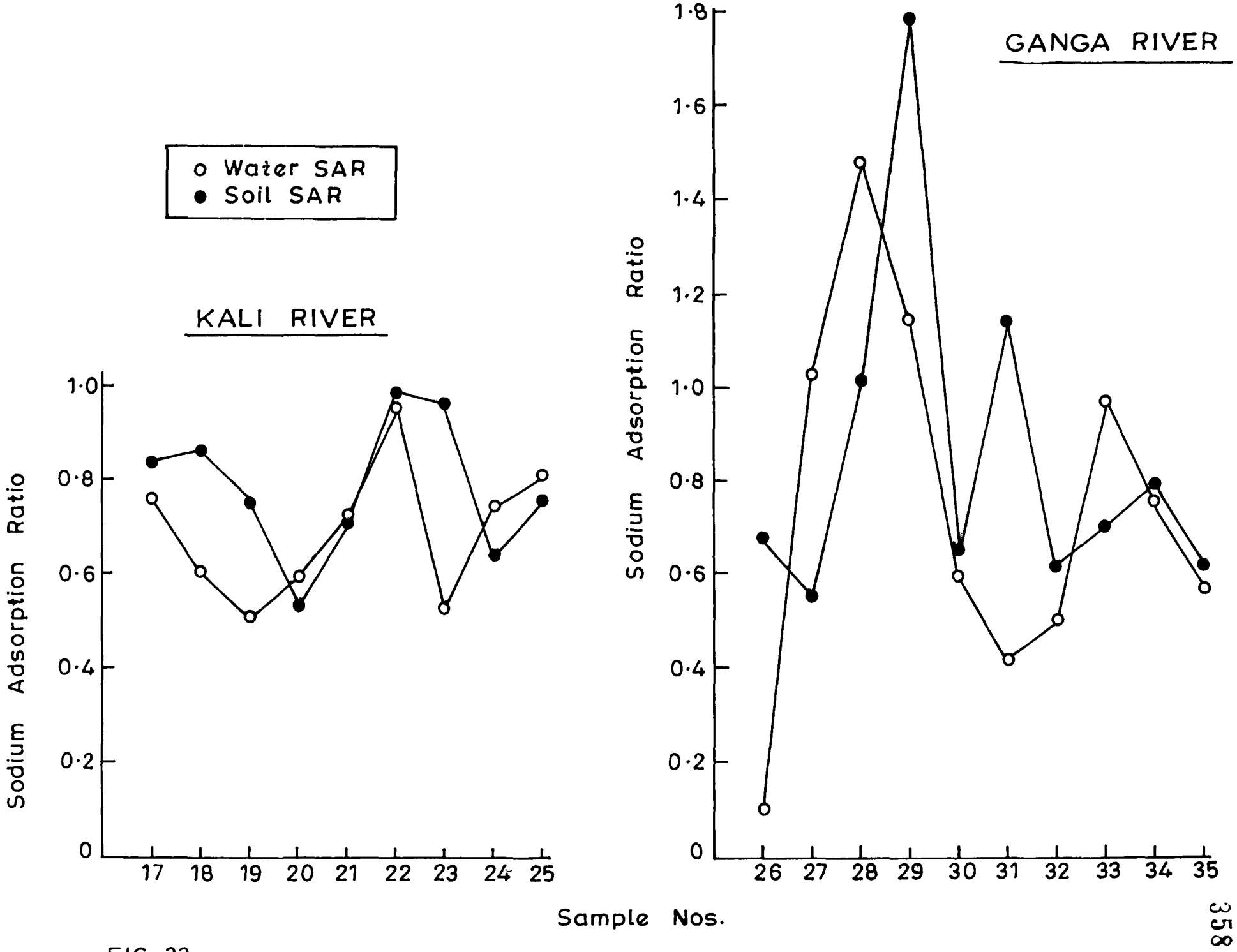

o Water SAR
● Soil SAR
KALI RIVER
GANGA RIVER
Sodium Adsorption Ratio
1·0
0·8
0·6
0·4
0·2
0
17 18 19 20 21 22 23 24 25
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0
26 27 28 29 30 31 32 33 34 35
Sample Nos.

FIG. 33

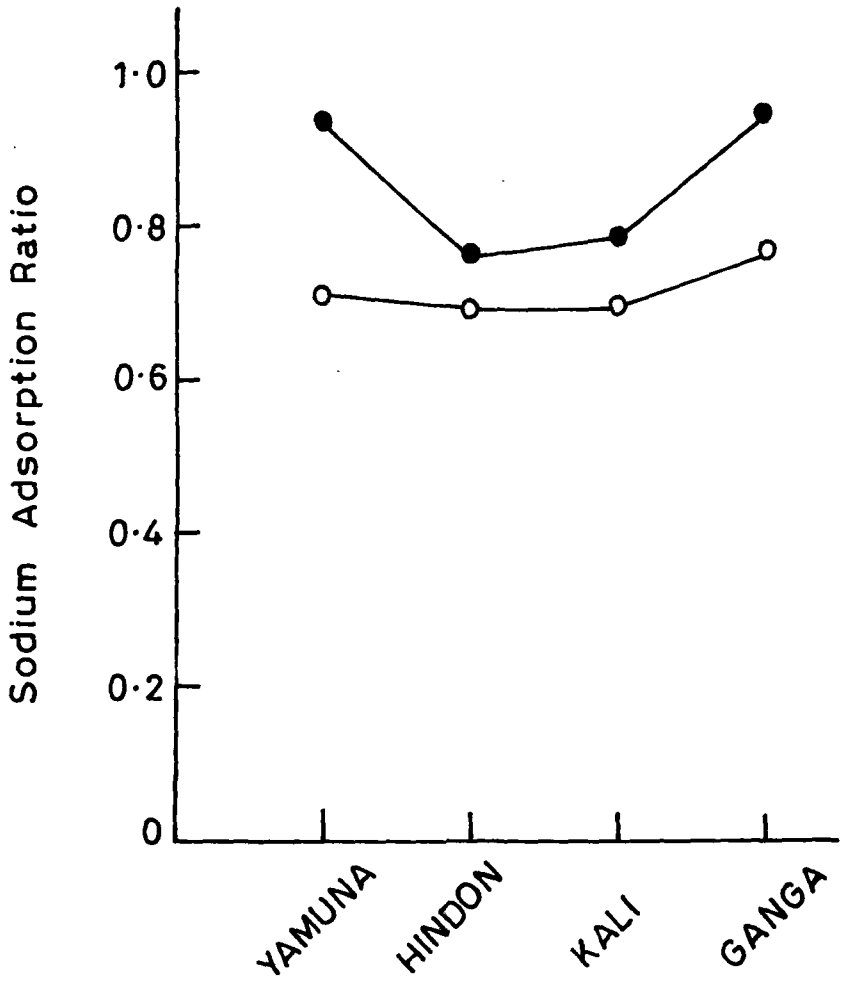


FIG. 34 Showing average Sodium Adsorption Ratio in river water and soil samples

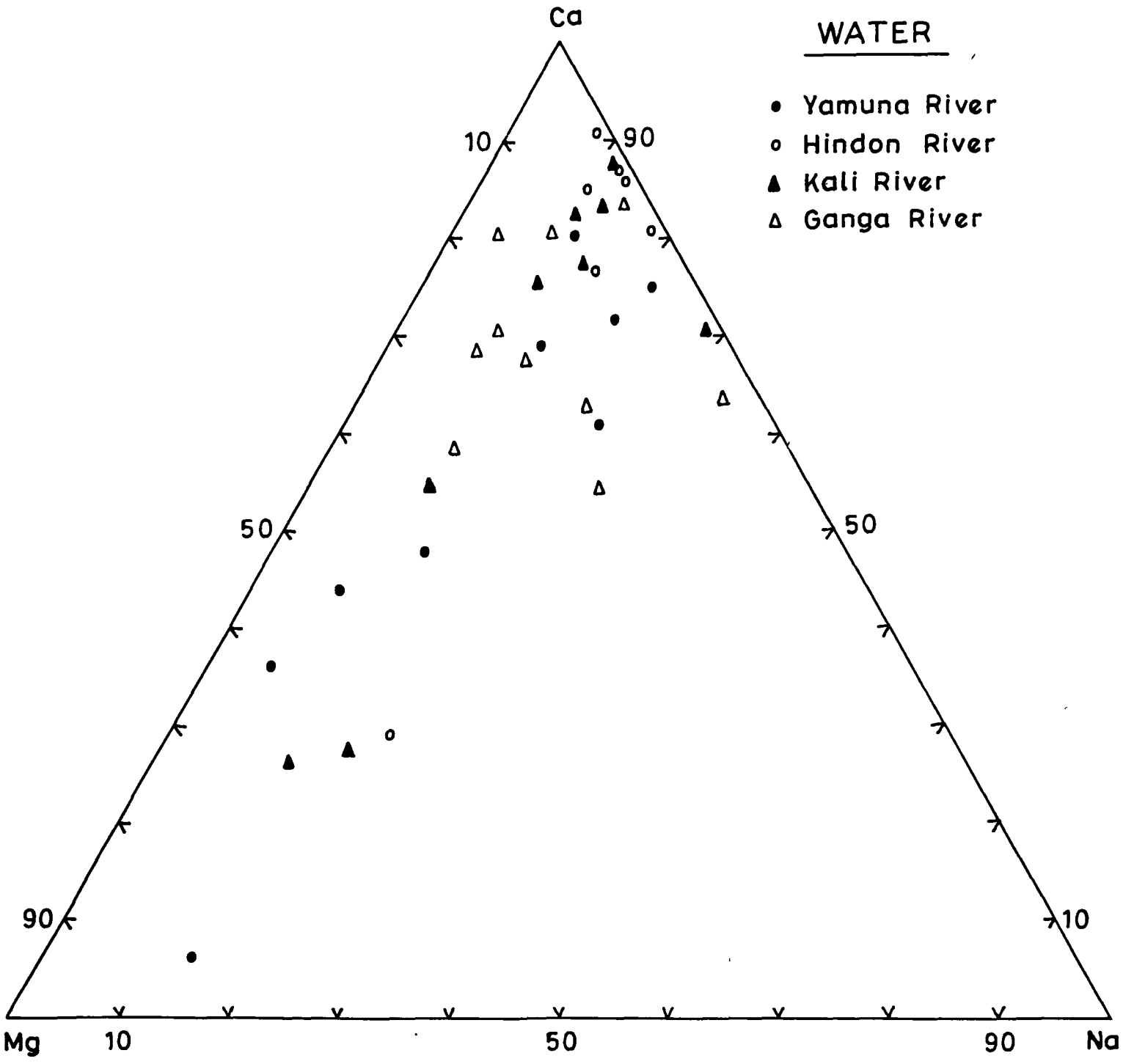


FIG. 35 Represents Ca – Mg – Na triangular diagram for river waters

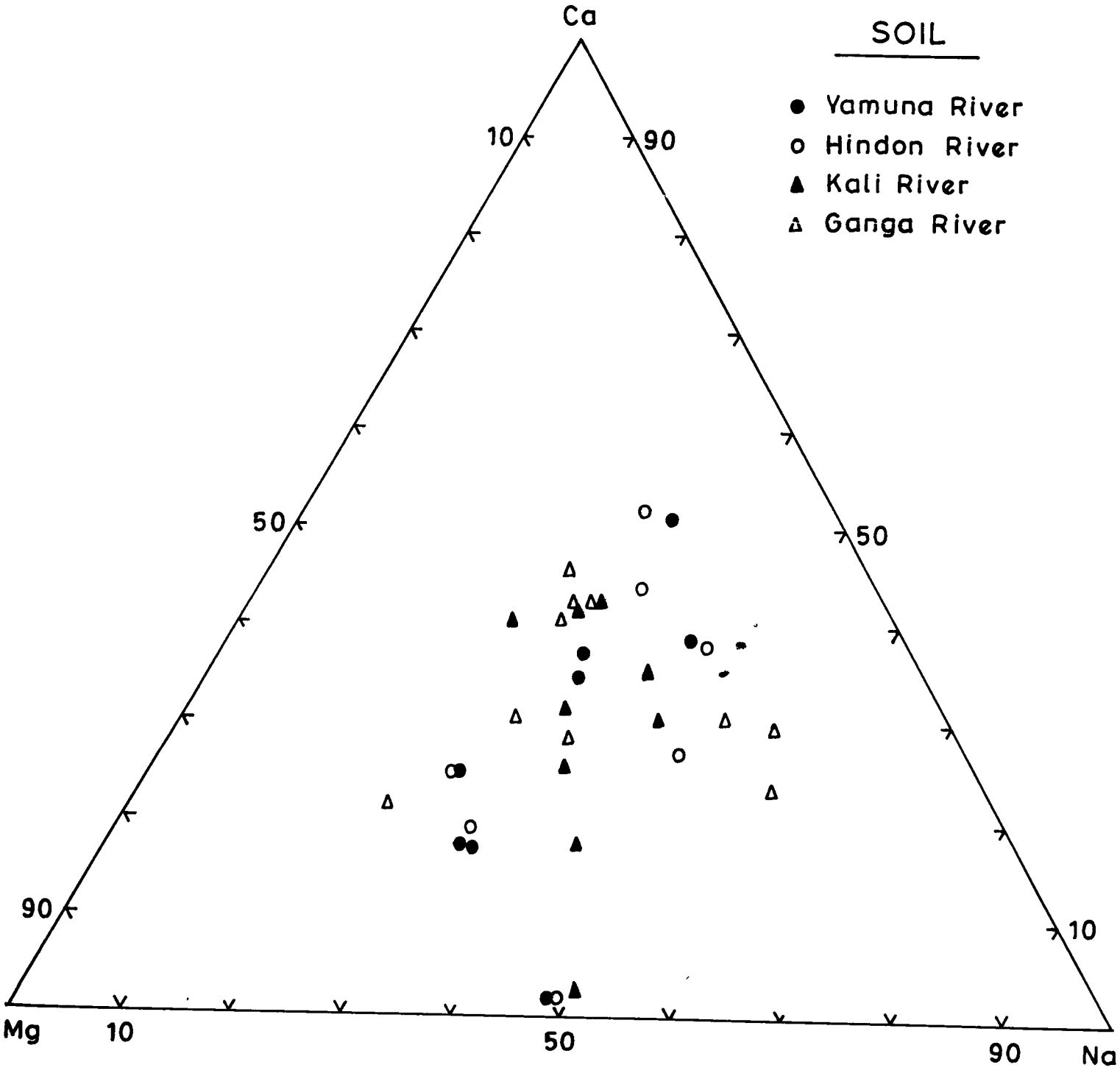


FIG. 36 Represents Ca-Mg-Na triangular diagram for river soils

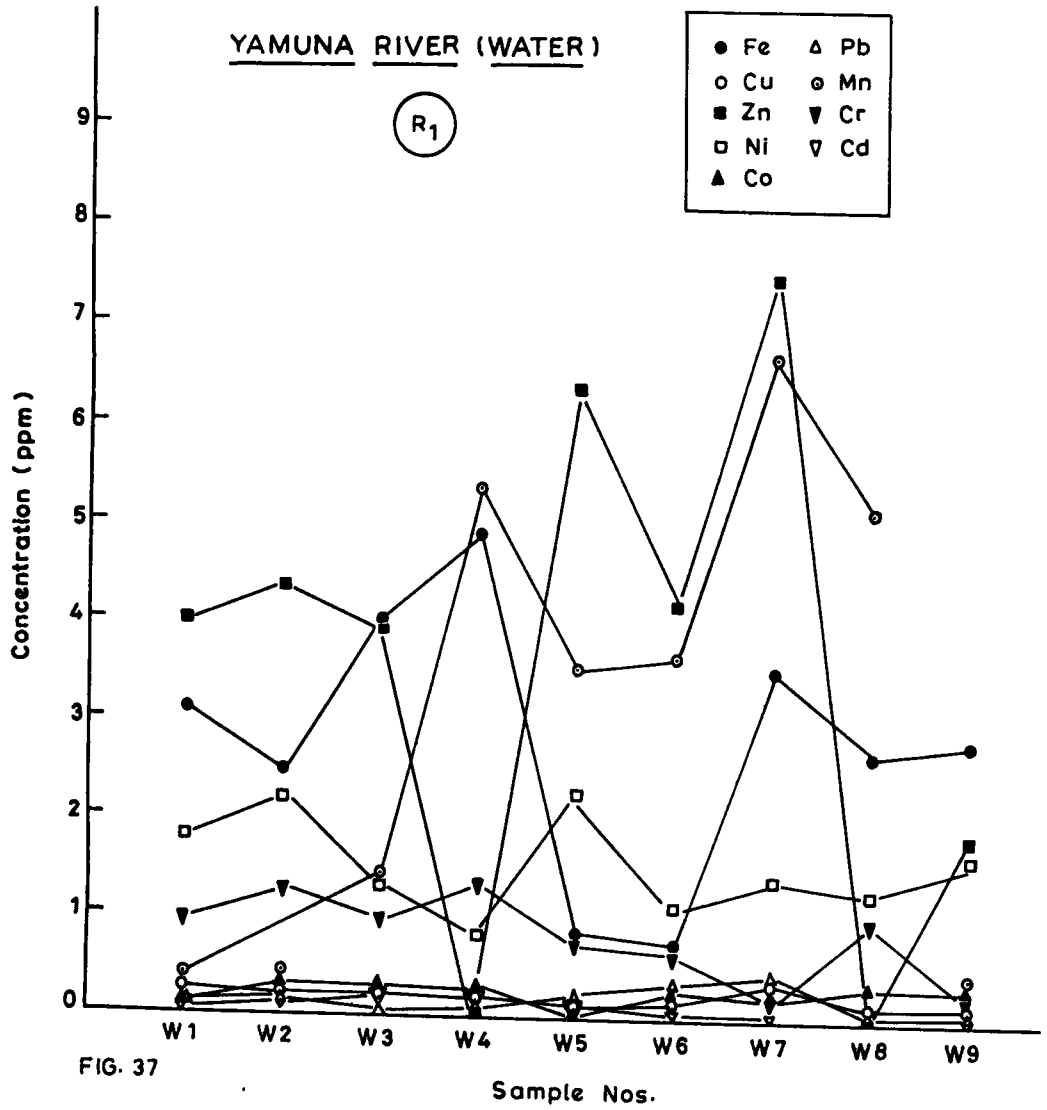


FIG. 37

FIG. 37 – 44 Concentration variation of trace metals in Yamuna, Hindon, Kali and Ganga river water samples of both sides (R_1 & R_2)

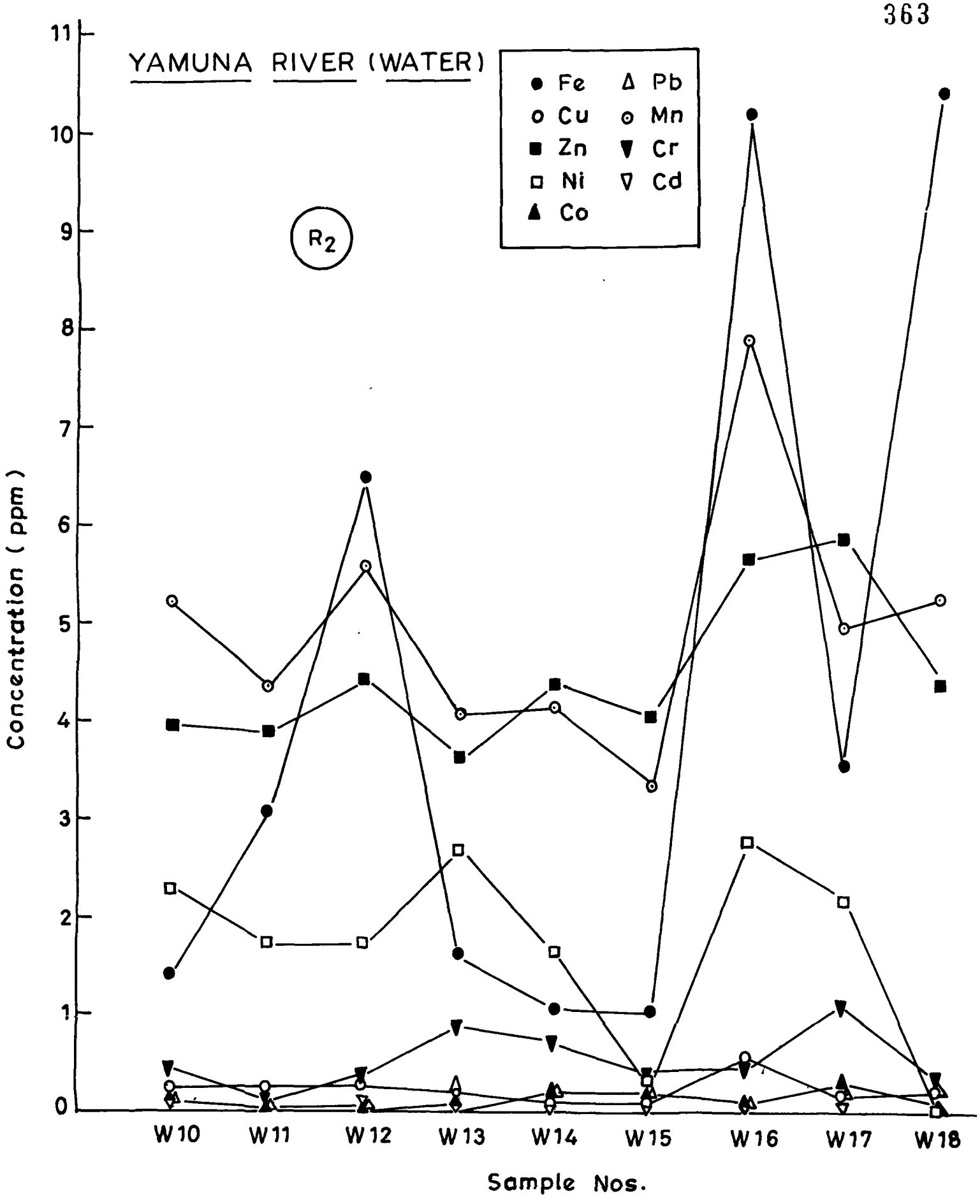

YAMUNA RIVER (WATER)
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
R2
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
W10
W11
W12
W13
W14
W15
W16
W17
W18
Sample Nos.

FIG. 38

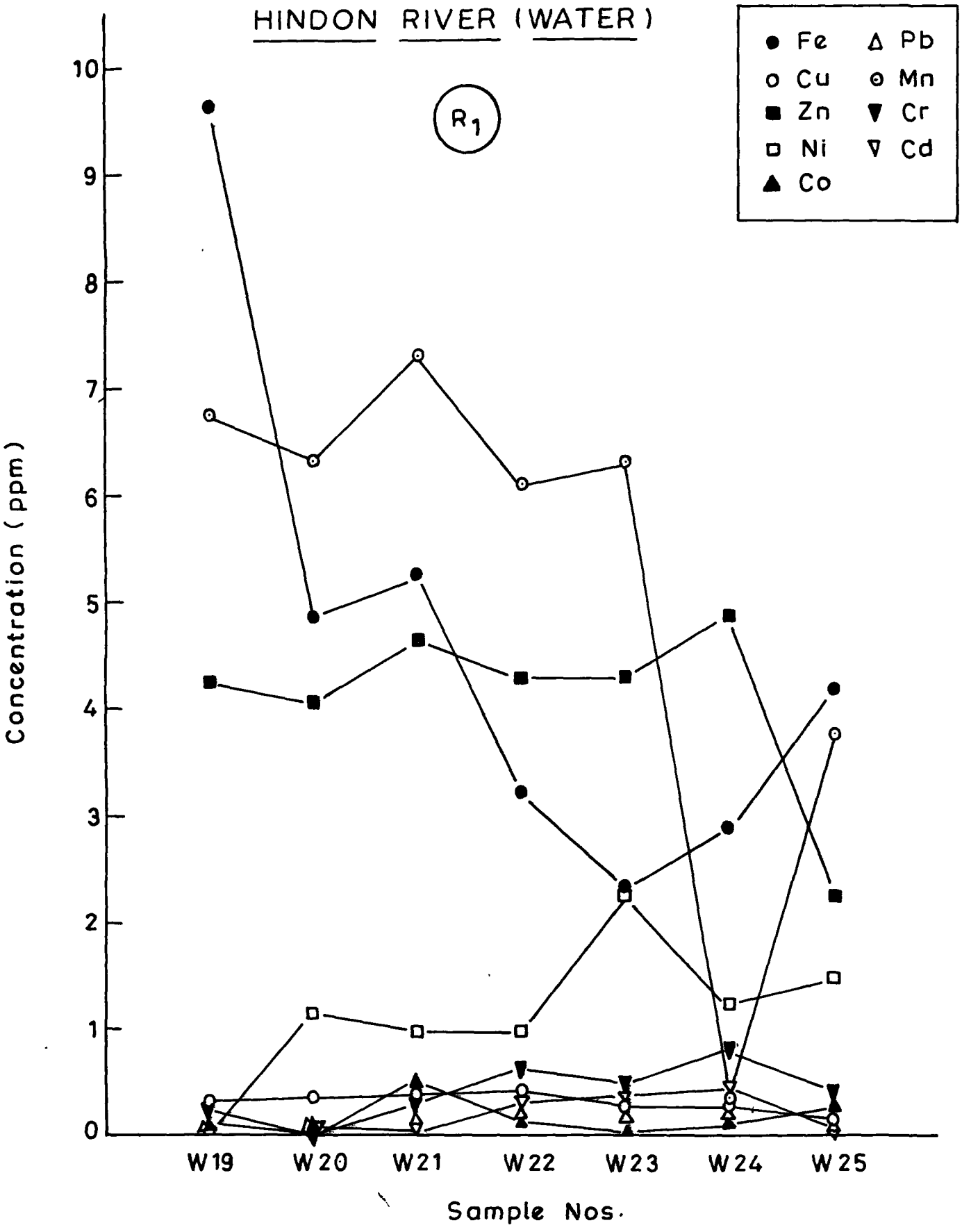

HINDON RIVER (WATER)
R1
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
W19
W20
W21
W22
W23
W24
W25
Sample Nos.

FIG. 39

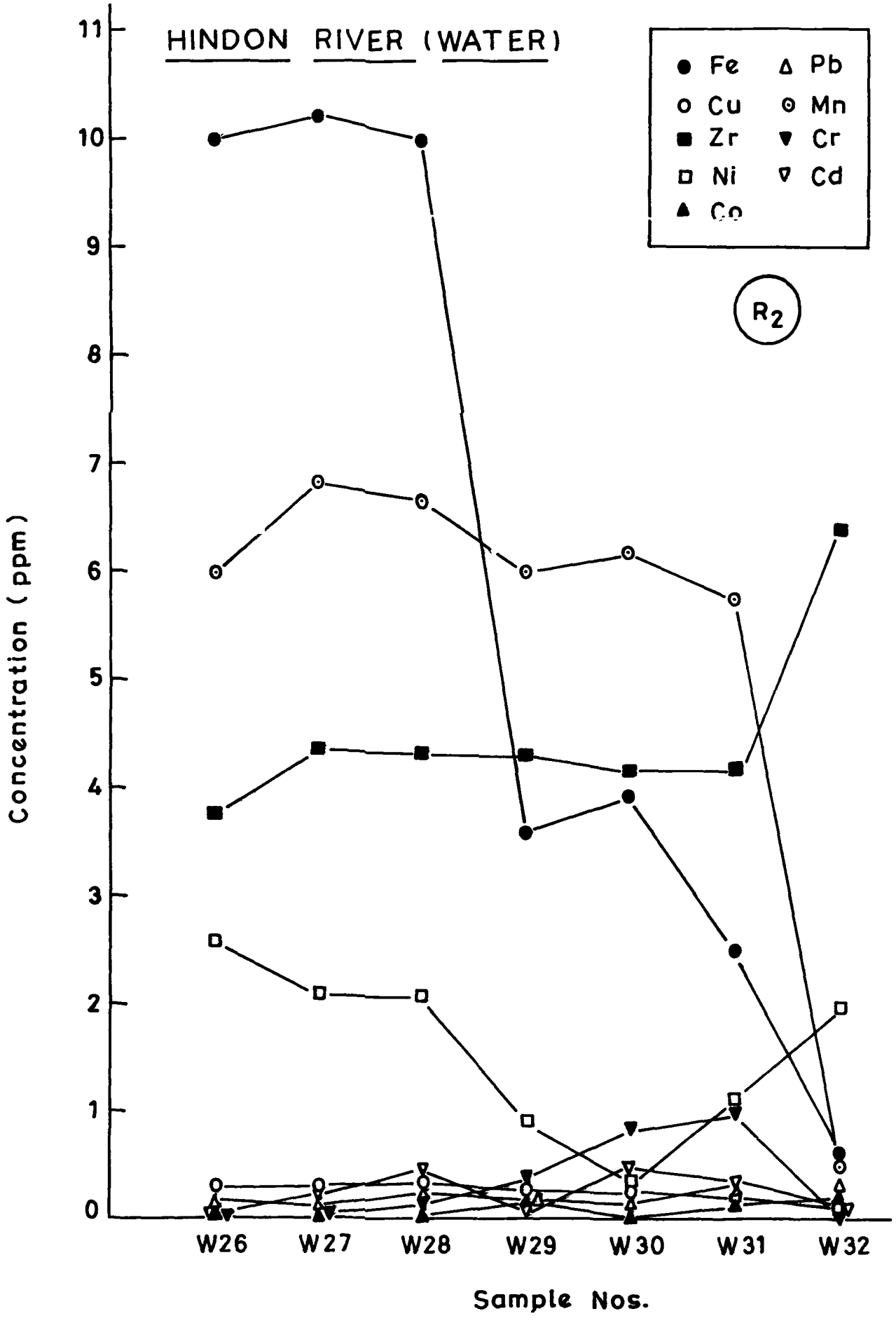

HINDON RIVER (WATER)
Fe
Cu
Zr
Ni
Co
Pb
Mn
Cr
Cd
R2
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
W26
W27
W28
W29
W30
W31
W32
Sample Nos.

FIG. 40

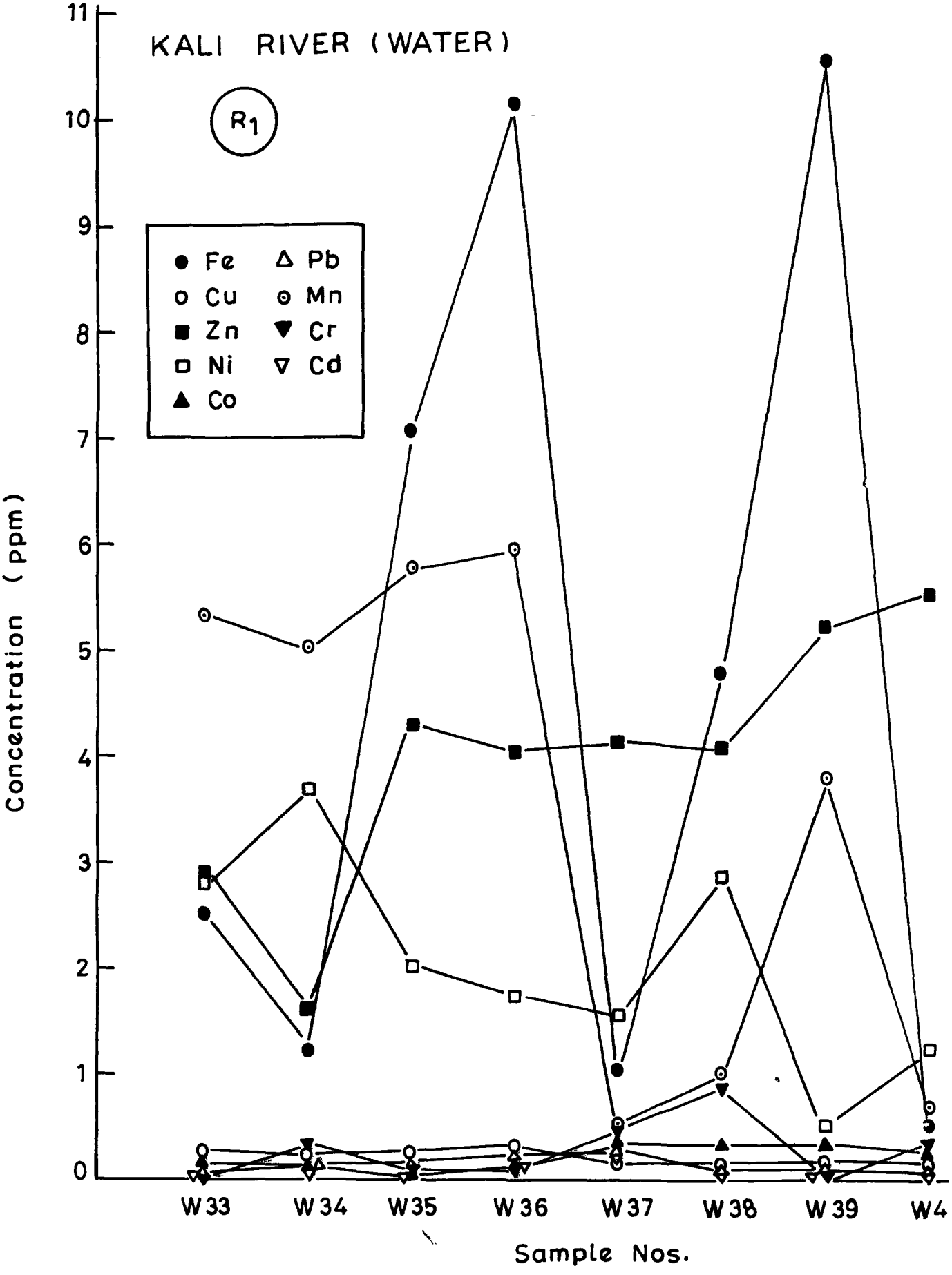

KALI RIVER (WATER)
R1
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
W33
W34
W35
W36
W37
W38
W39
W4
Sample Nos.

FIG. 41

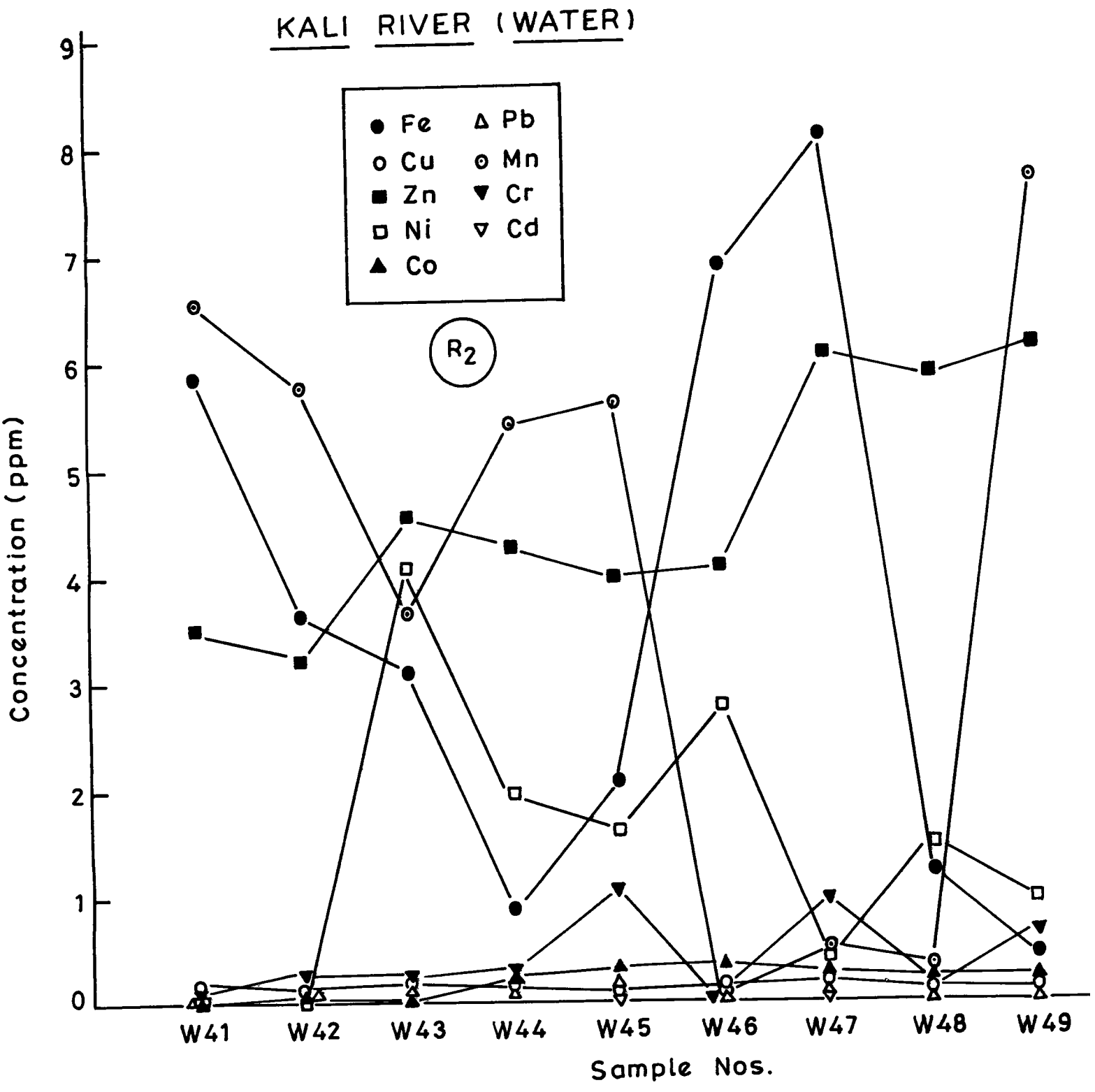

KALI RIVER (WATER)
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
R2
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
W41
W42
W43
W44
W45
W46
W47
W48
W49
Sample Nos.

FIG. 42

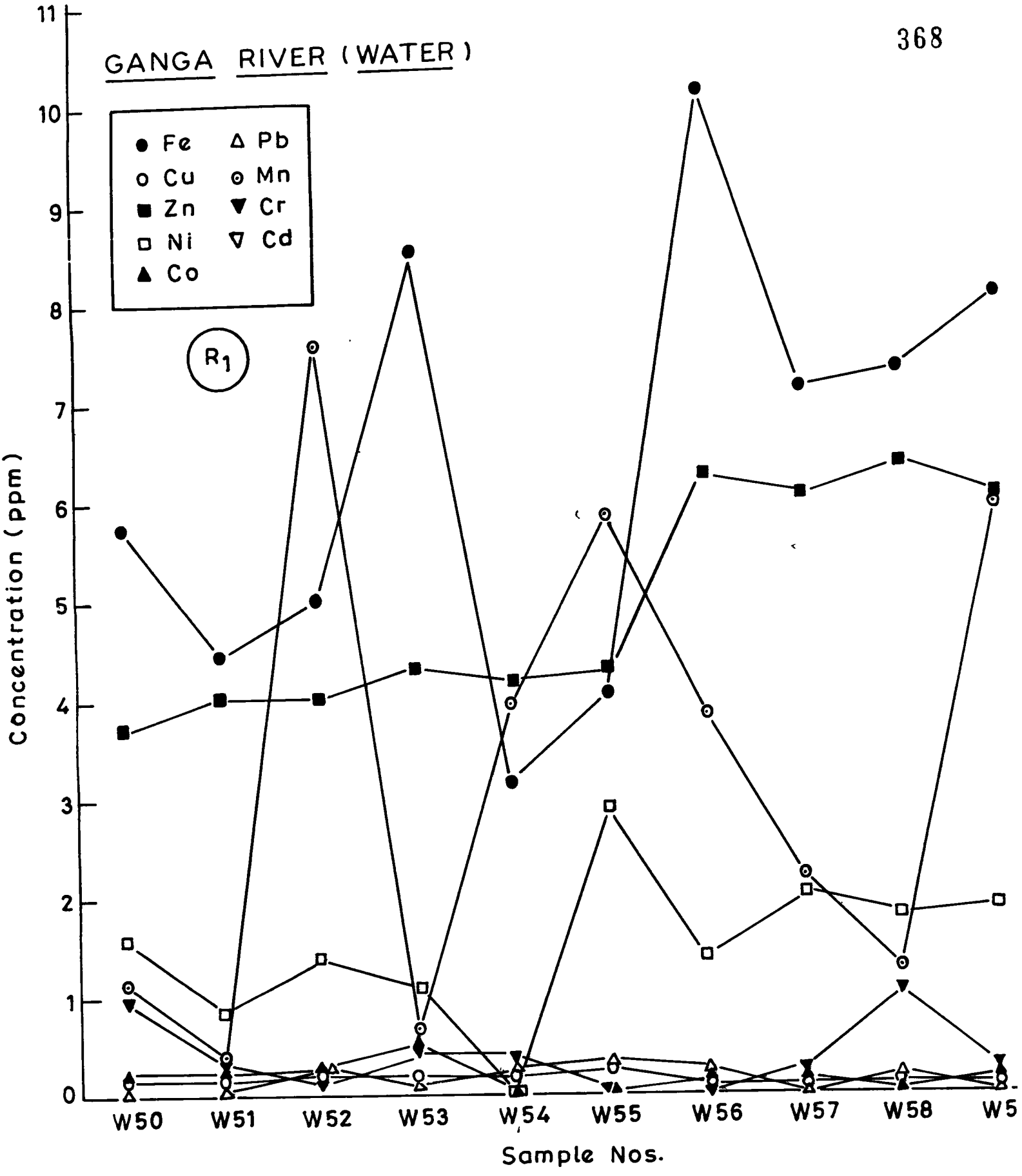

GANGA RIVER (WATER)
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
R1
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
W50
W51
W52
W53
W54
W55
W56
W57
W58
W5
Sample Nos.

FIG. 43

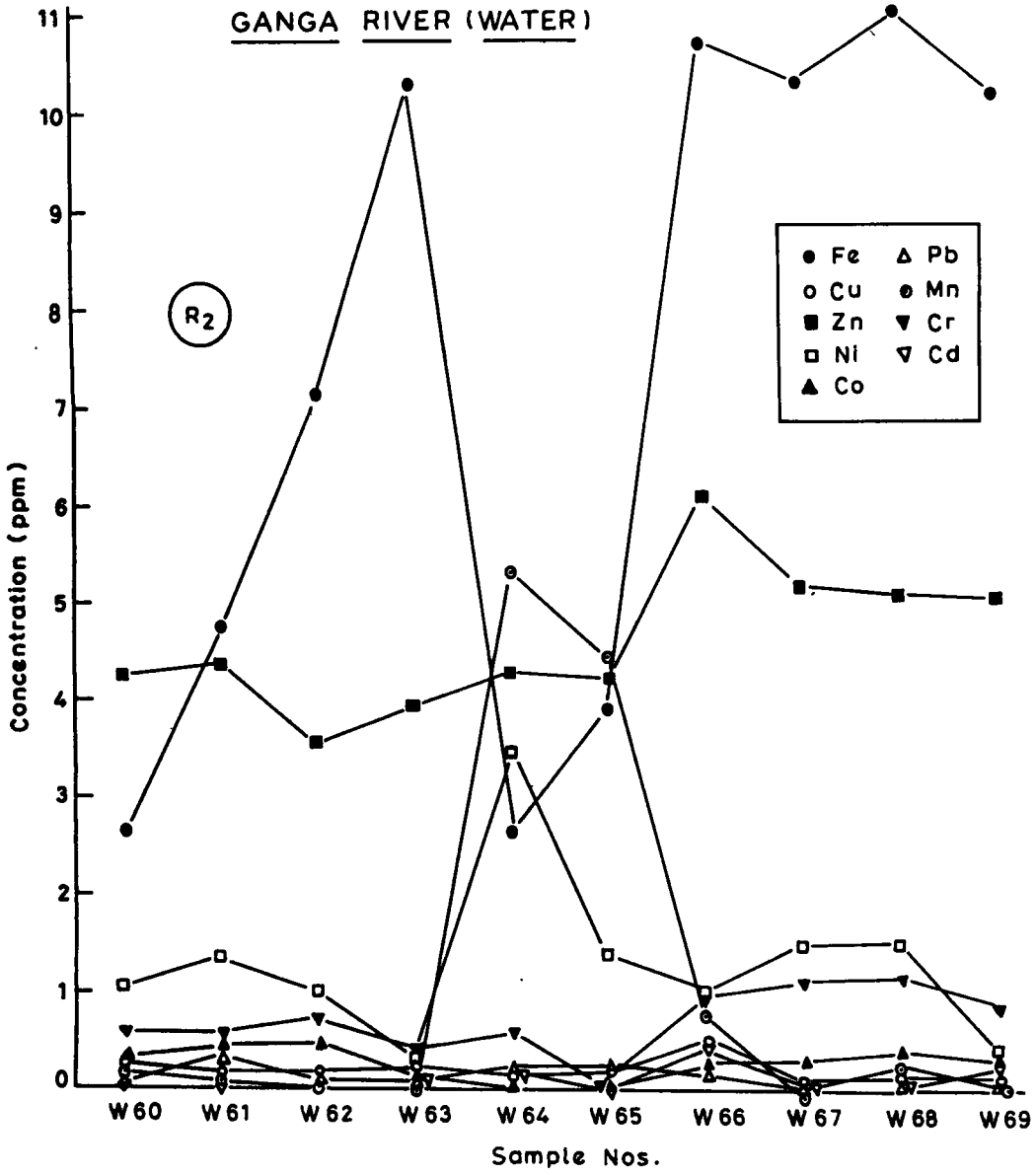

GANGA RIVER (WATER)
R2
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
W60
W61
W62
W63
W64
W65
W66
W67
W68
W69
Sample Nos.

FIG. 44

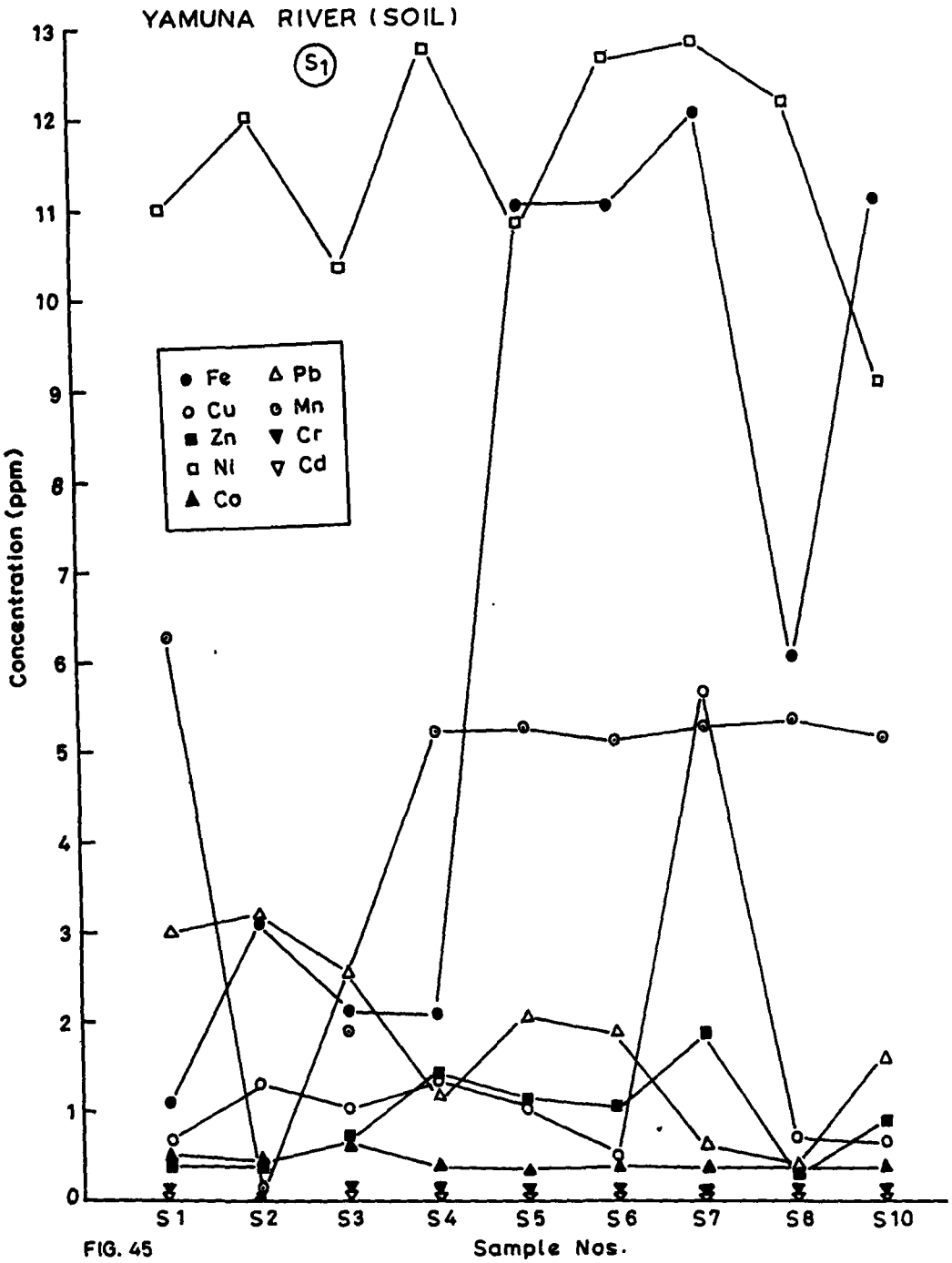


FIG. 45

FIG. 45 - 52 Concentration variation of trace metals in Yamuna, Hindon, Kali and Ganga river soil samples of both sides (S_1 & S_2)

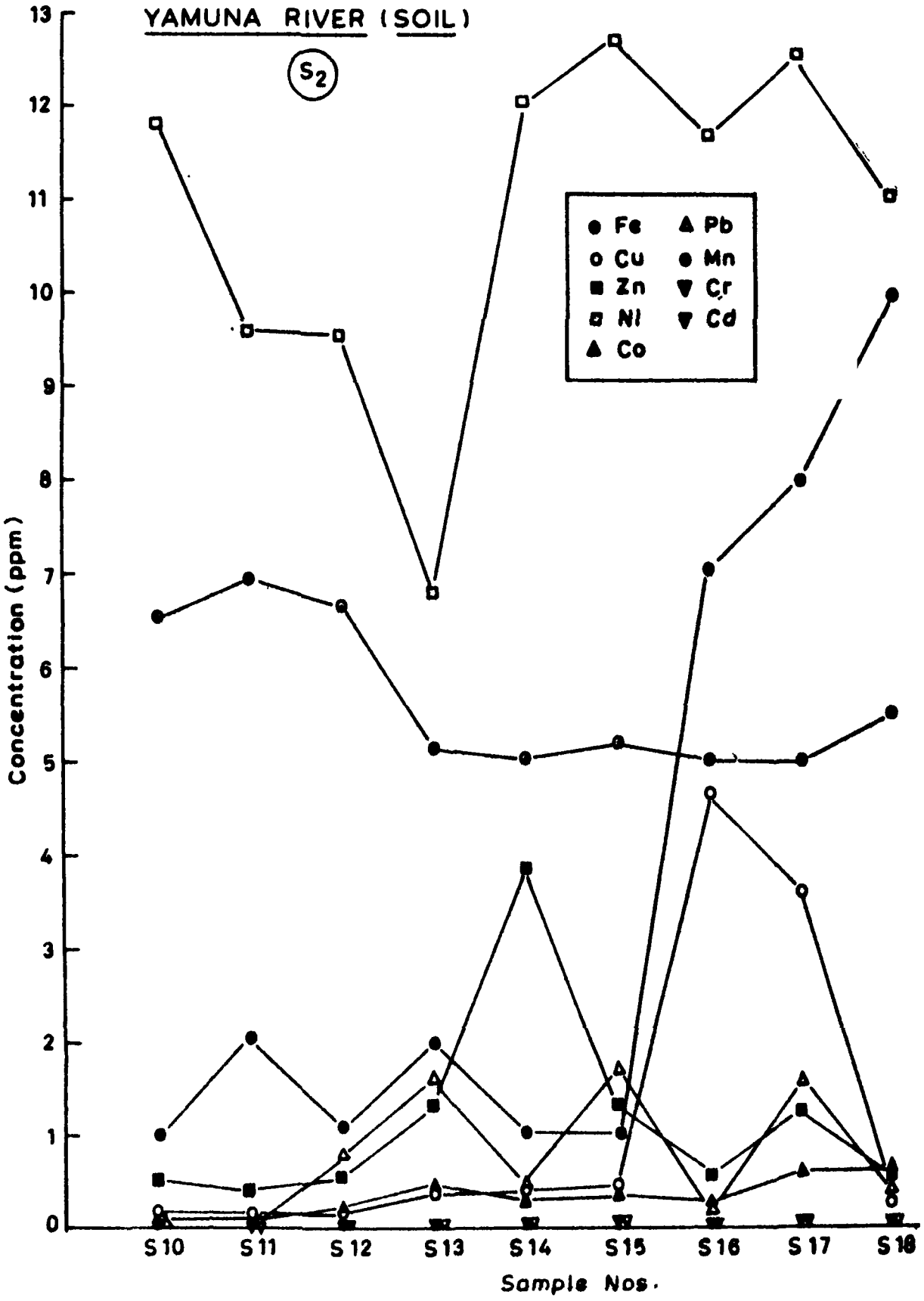

YAMUNA RIVER (SOIL)
S2
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
S10
S11
S12
S13
S14
S15
S16
S17
S18
Sample Nos.

FIG. 46

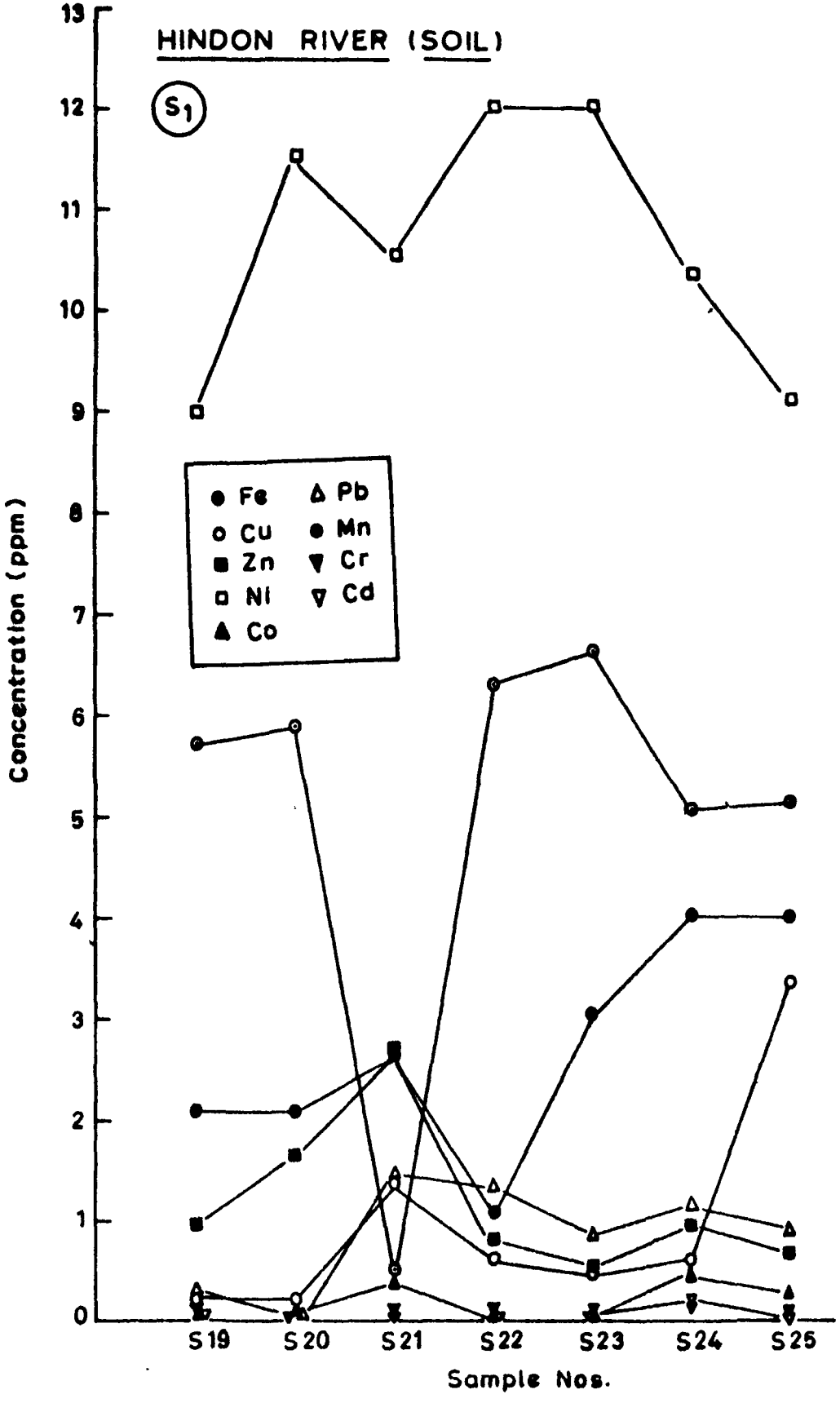

HINDON RIVER (SOIL)
S1
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
S19
S20
S21
S22
S23
S24
S25
Sample Nos.

FIG. 47

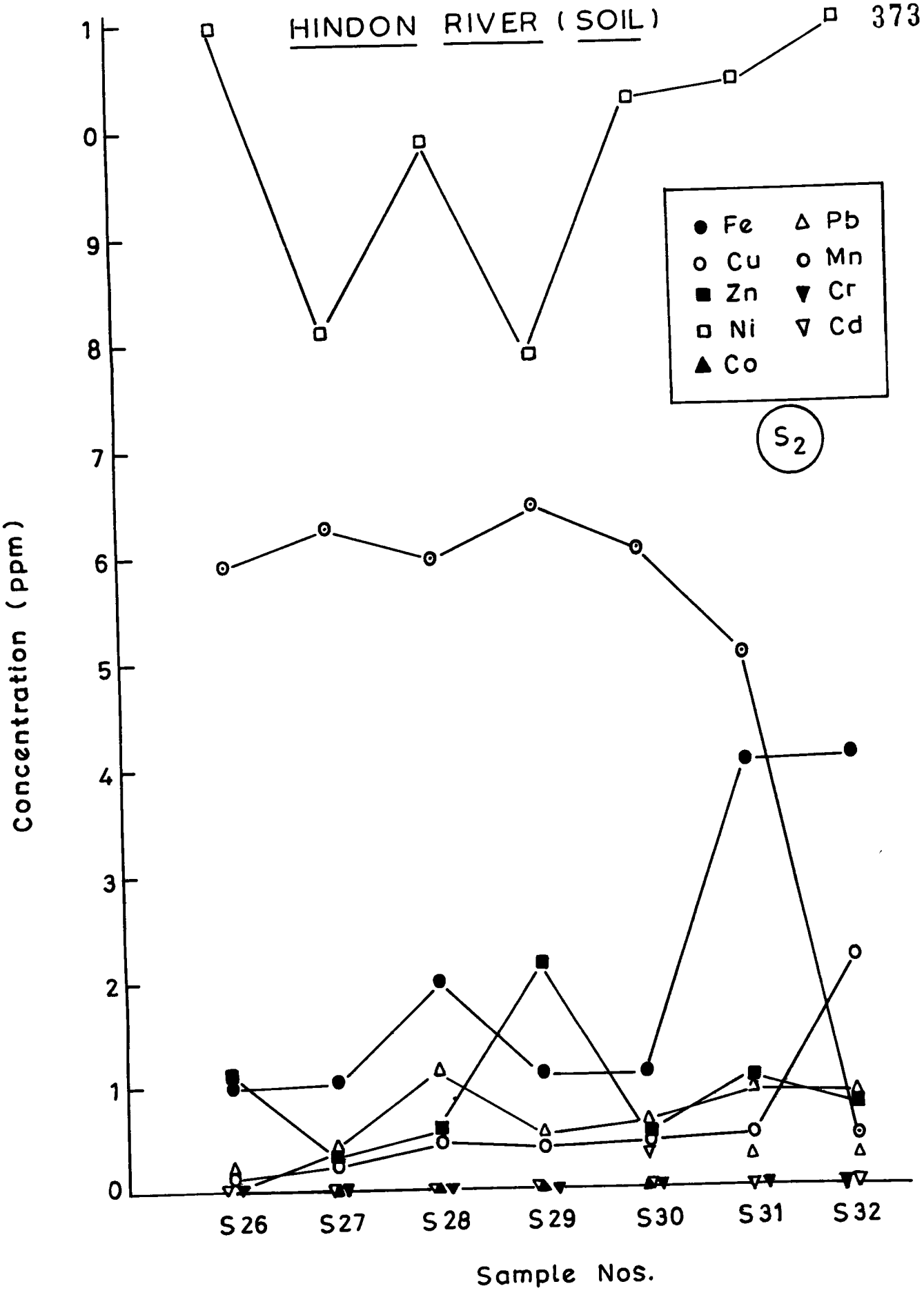

HINDON RIVER (SOIL)
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
S2
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
S26
S27
S28
S29
S30
S31
S32
Sample Nos.

FIG. 48

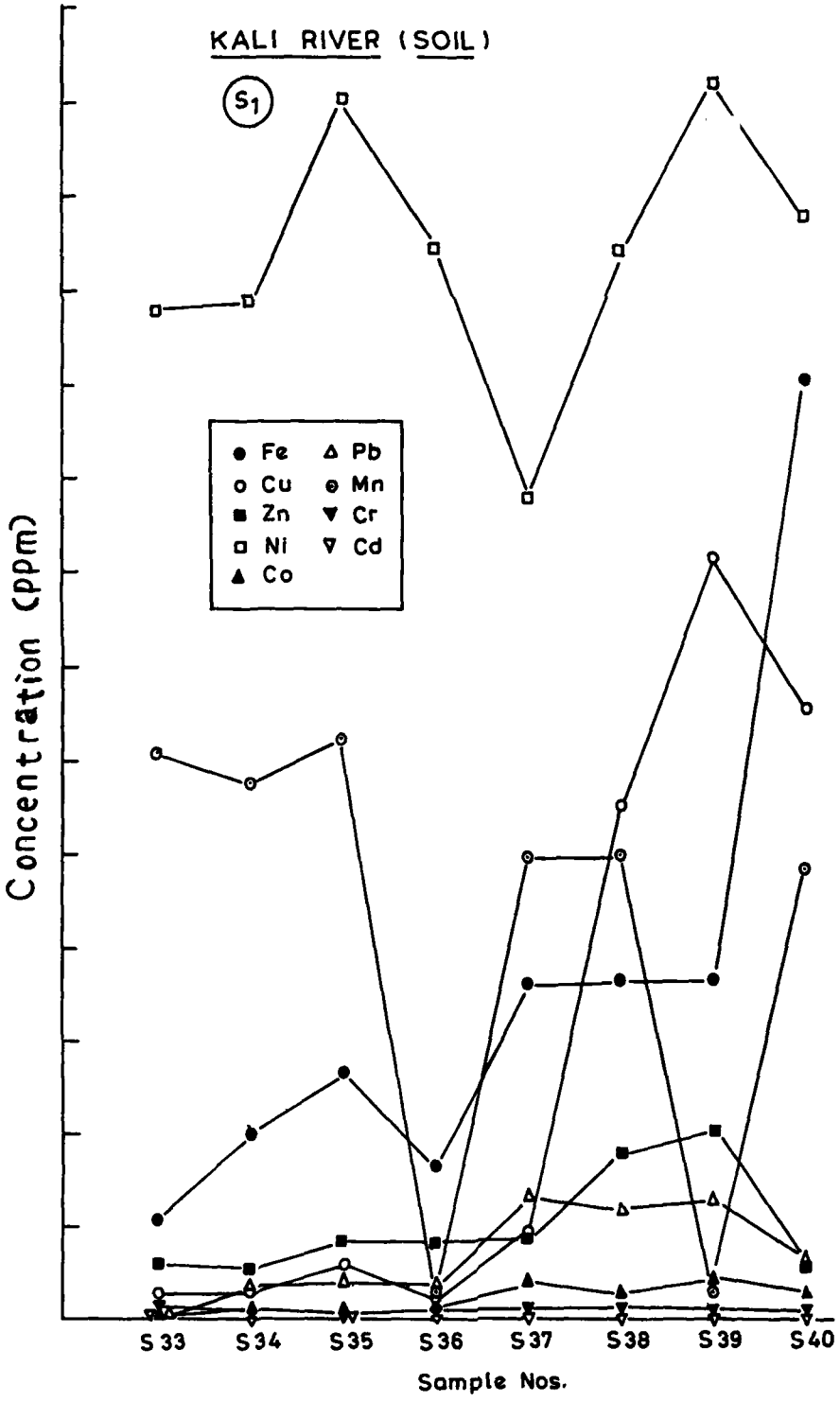


FIG. 49

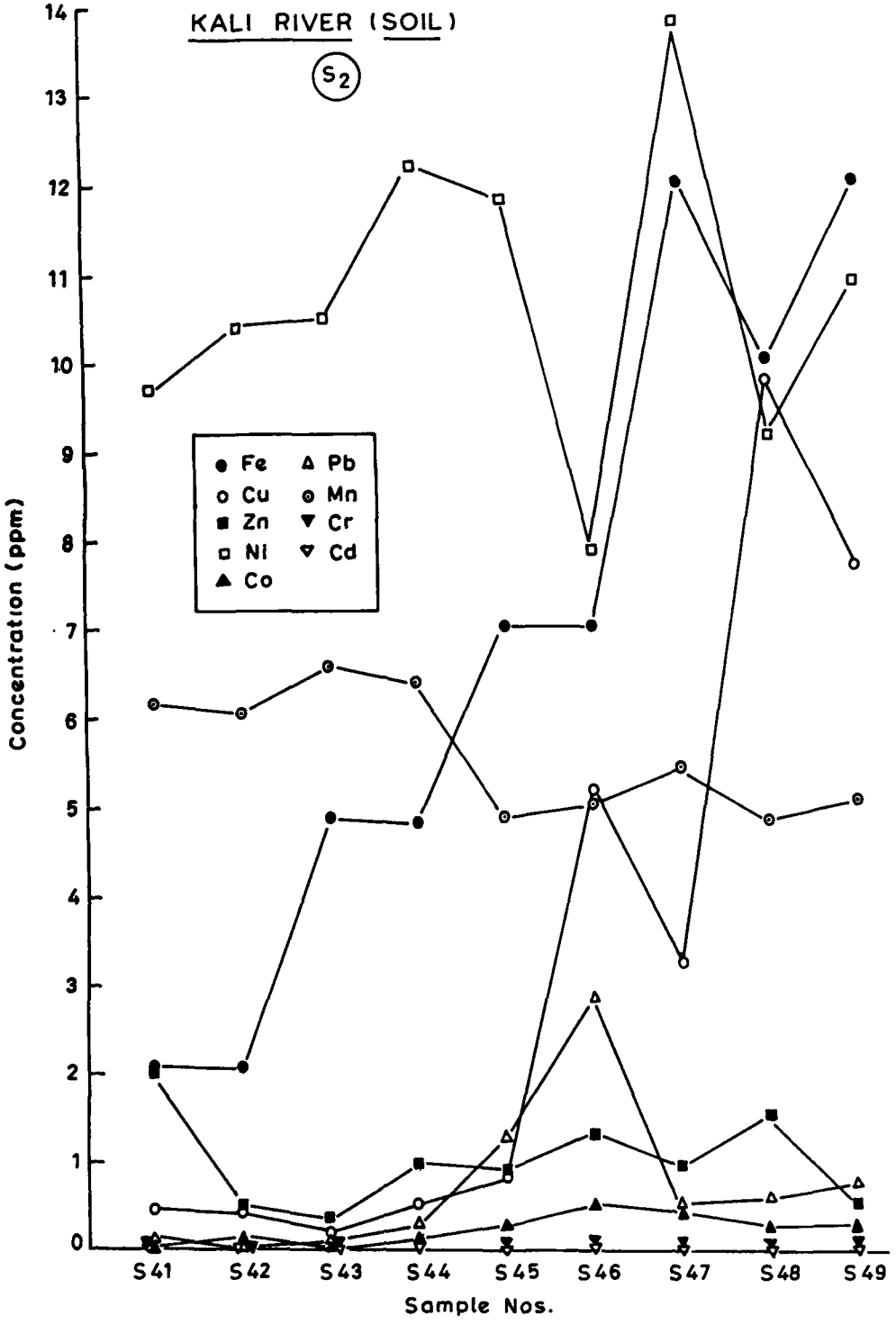

KALI RIVER (SOIL)
S2
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
S41
S42
S43
S44
S45
S46
S47
S48
S49
Sample Nos.

FIG. 50

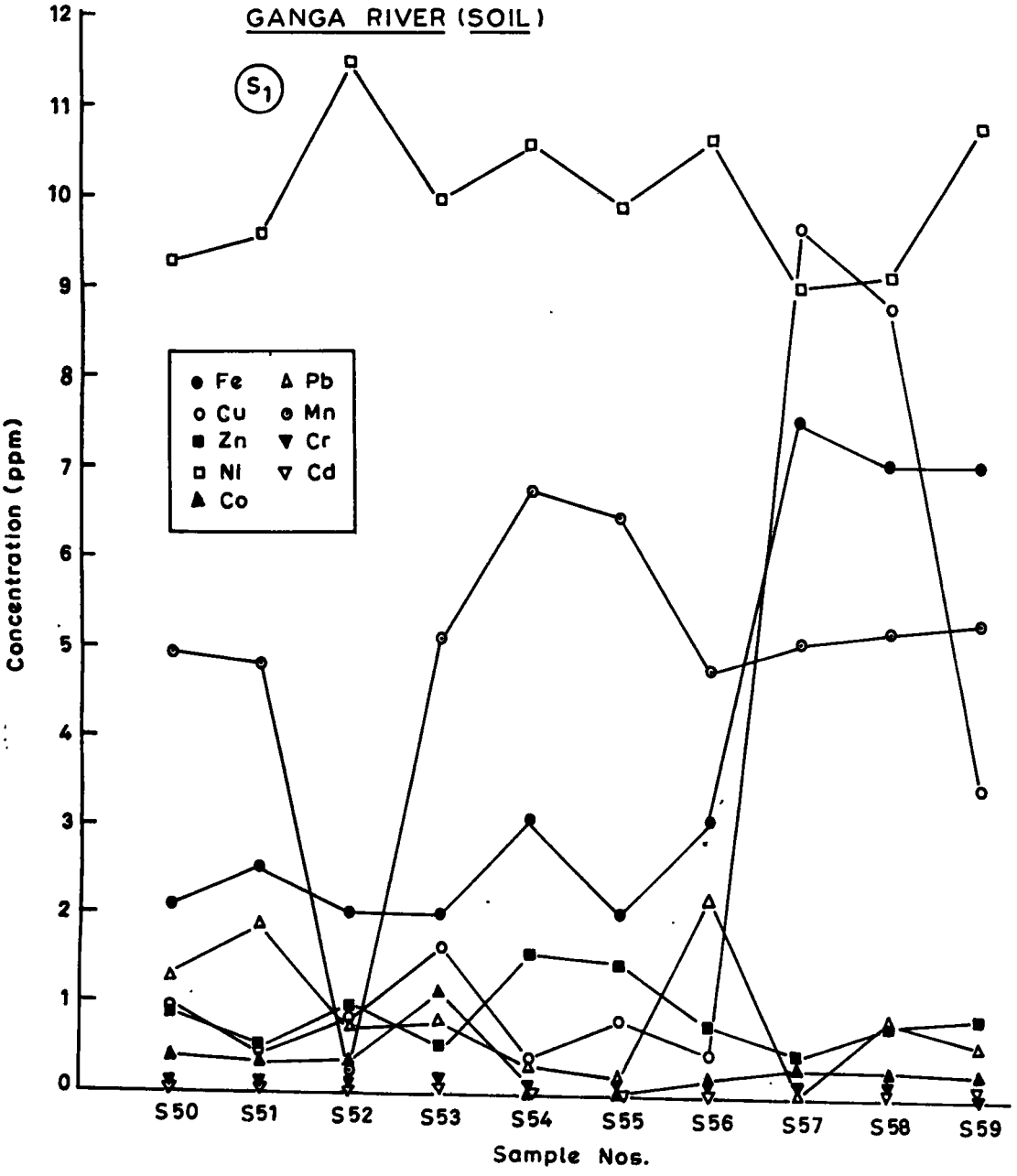

GANGA RIVER (SOIL)
S1
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
S50
S51
S52
S53
S54
S55
S56
S57
S58
S59
Sample Nos.

FIG. 51

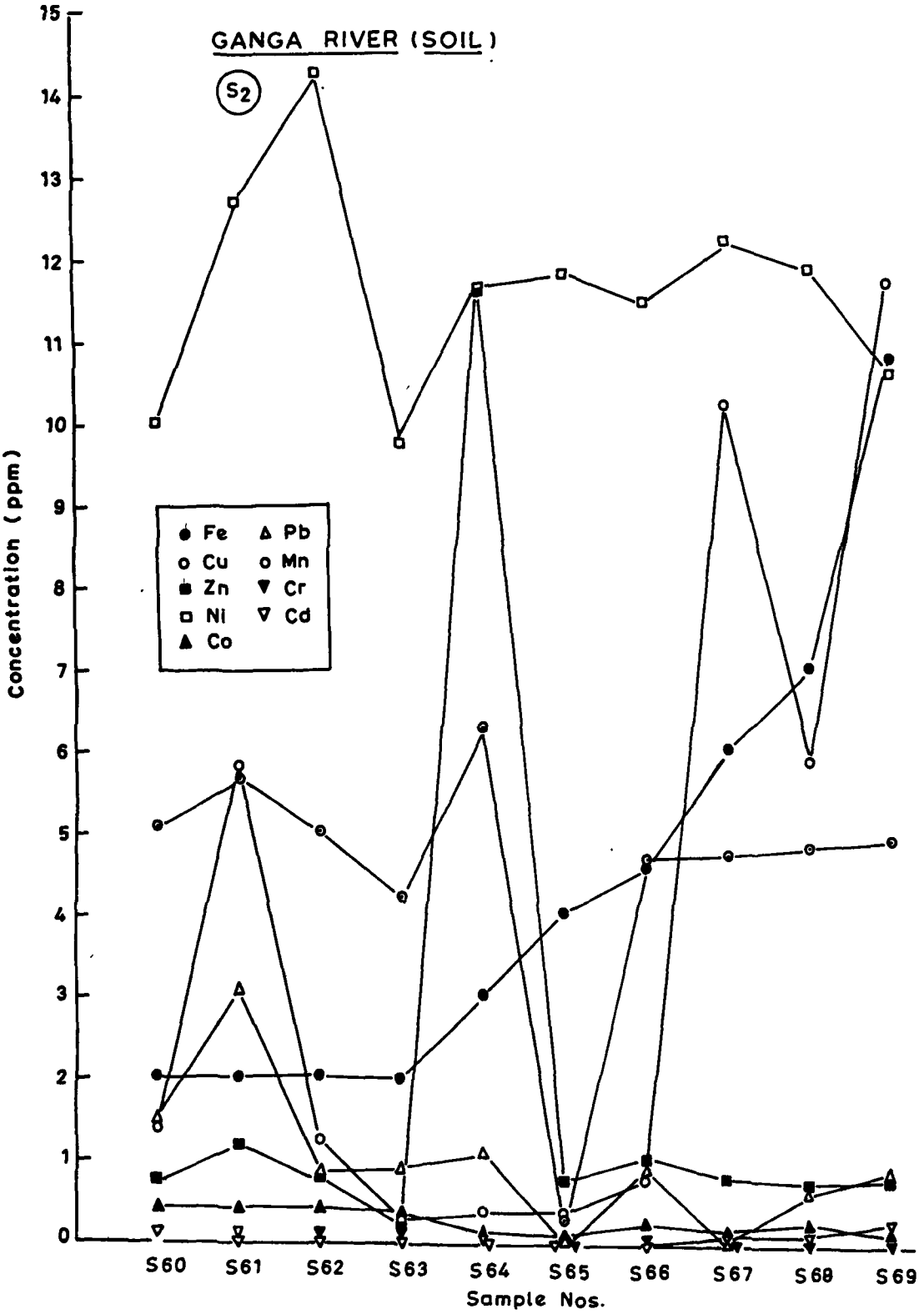

GANGA RIVER (SOIL)
S2
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Concentration (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
S60
S61
S62
S63
S64
S65
S66
S67
S68
S69
Sample Nos.

FIG. 52

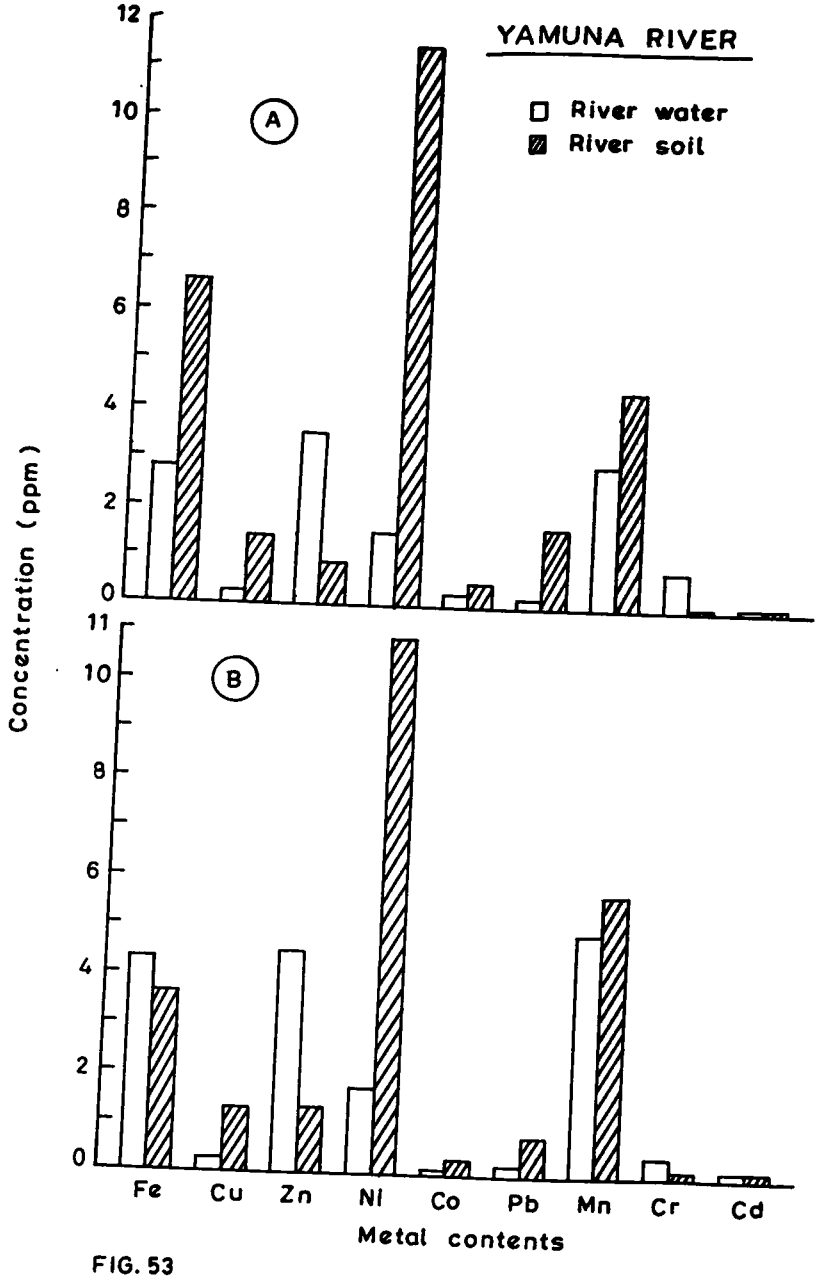


FIG. 53

FIG. 53 – 56 Average concentration of trace metals in Yamuna, Hindon, Kali and Ganga river water and soil of both sides (A & B)

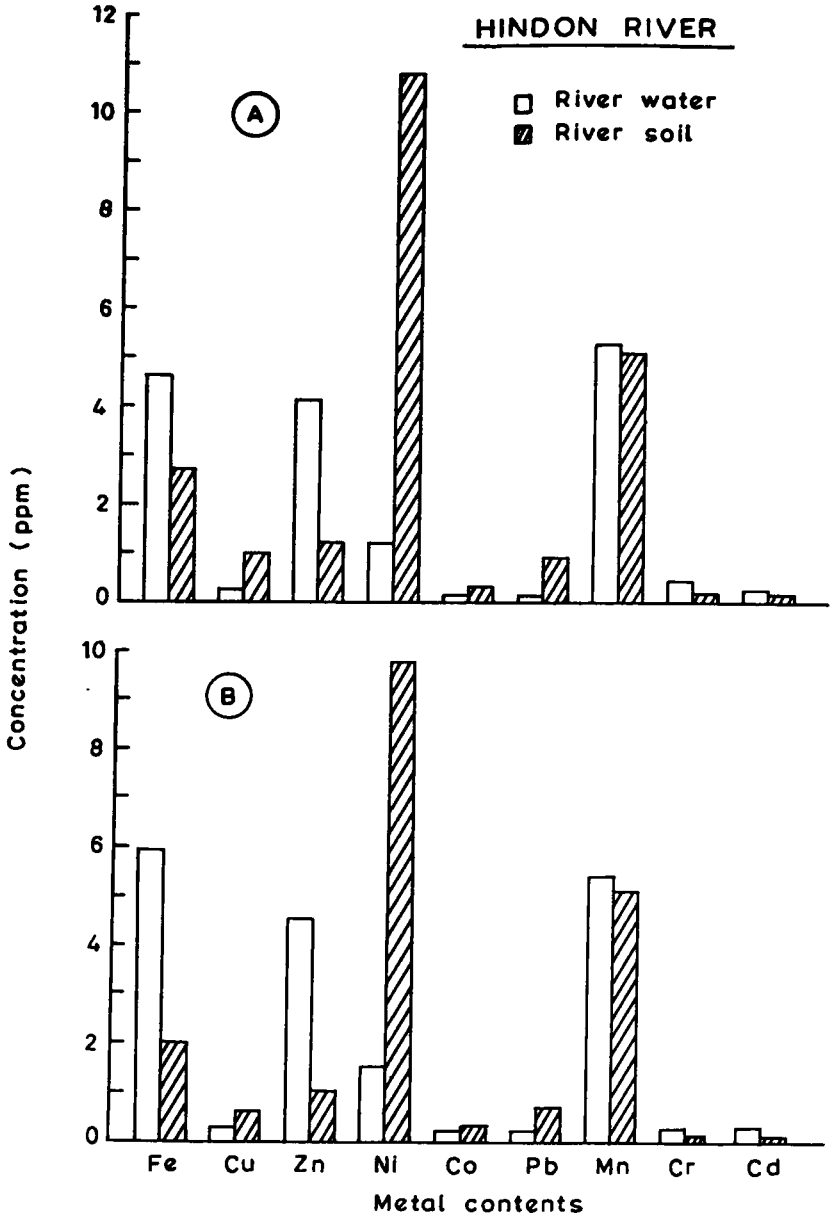


FIG. 54

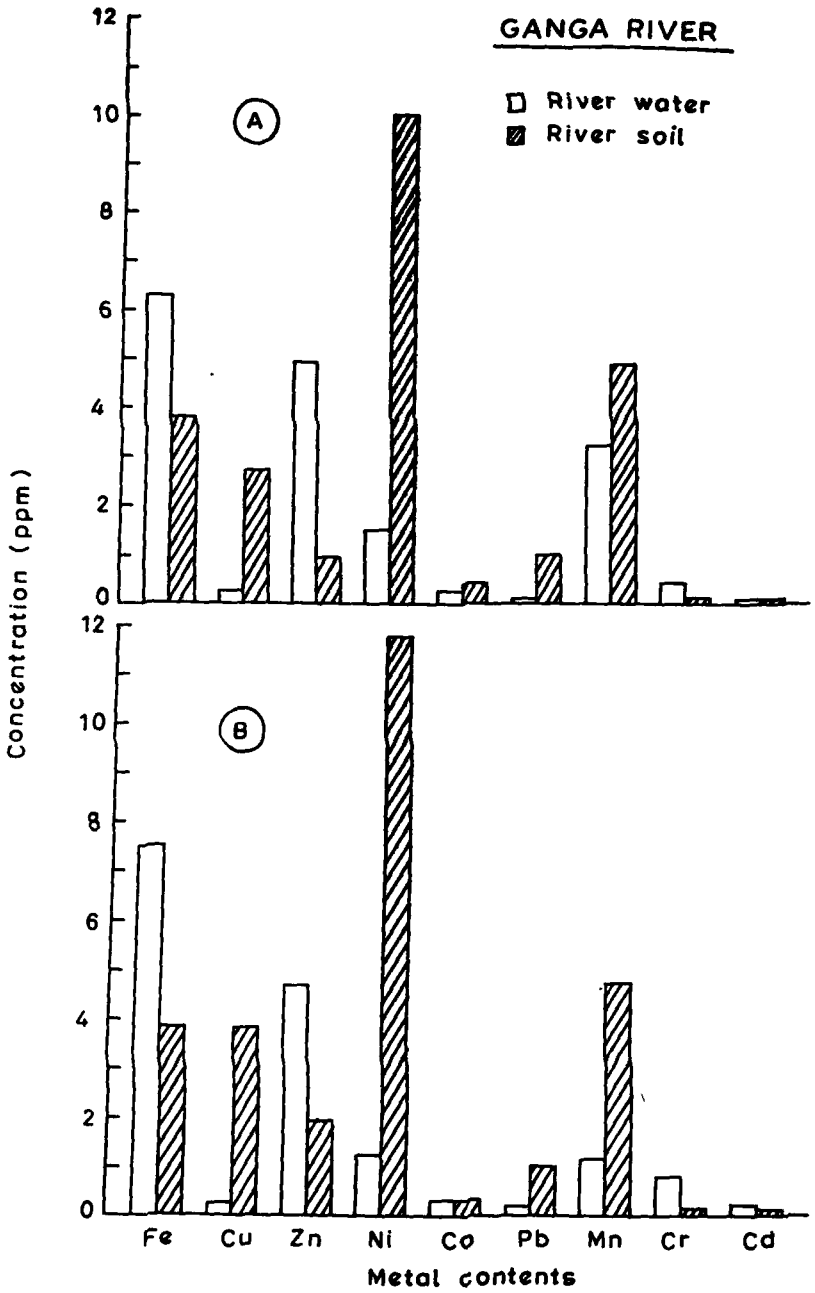

GANGA RIVER
River water
River soil
A
B
Concentration (ppm)
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Metal contents

FIG. 56

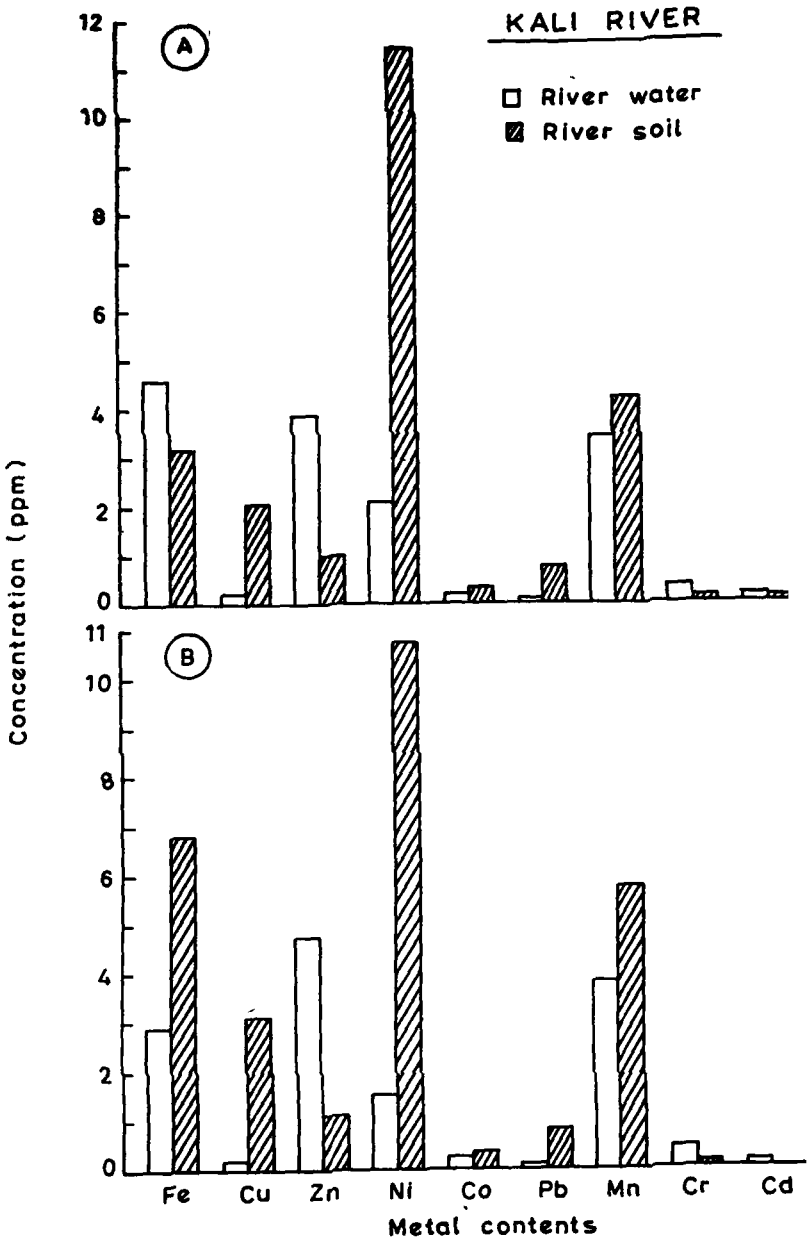

KALI RIVER
River water
River soil
A
B
Concentration (ppm)
Fe
Cu
Zn
Ni
Co
Pb
Mn
Cr
Cd
Metal contents

FIG. 55

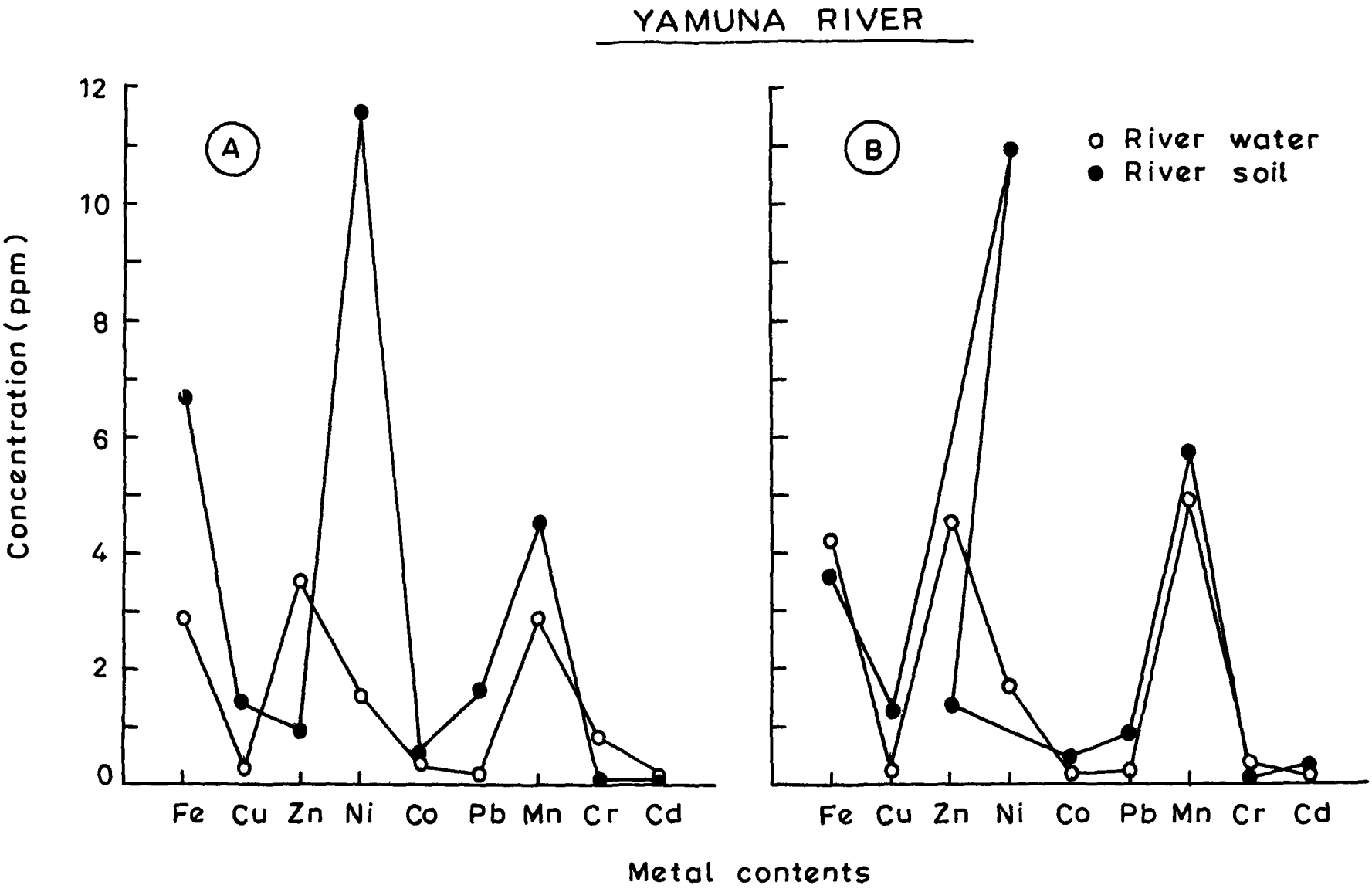


FIG. 57

FIG. 57 – 60 Relationship of average trace metal contents in Yamuna, Hindon, Kali and Ganga river water and soil of both sides (A & B)

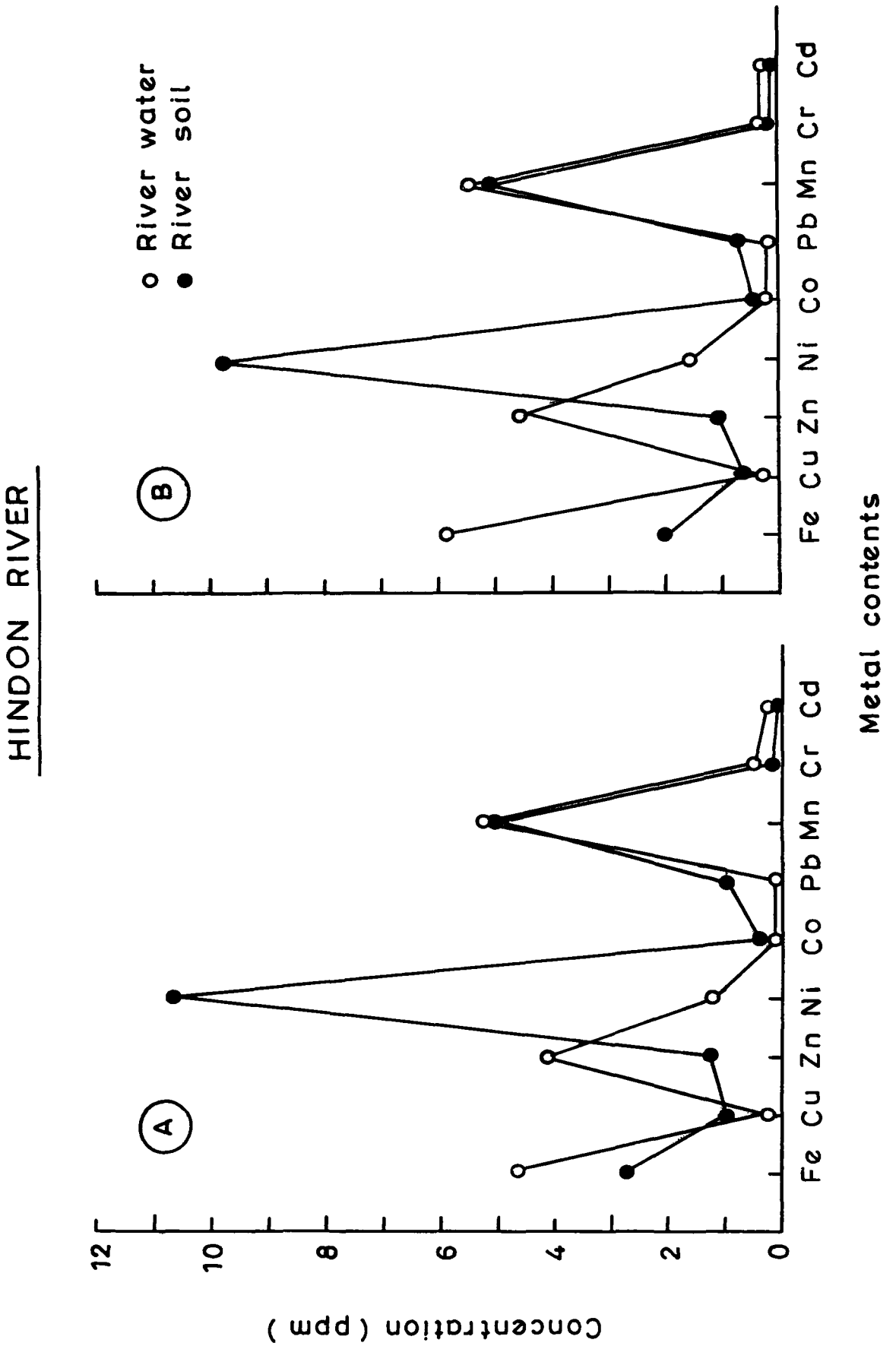

HINDON RIVER
A
B
o River water
● River soil
Concentration (ppm)
12
10
8
6
4
2
0
Fe Cu Zn Ni Co Pb Mn Cr Cd
Fe Cu Zn Ni Co Pb Mn Cr Cd
Metal contents

FIG. 58

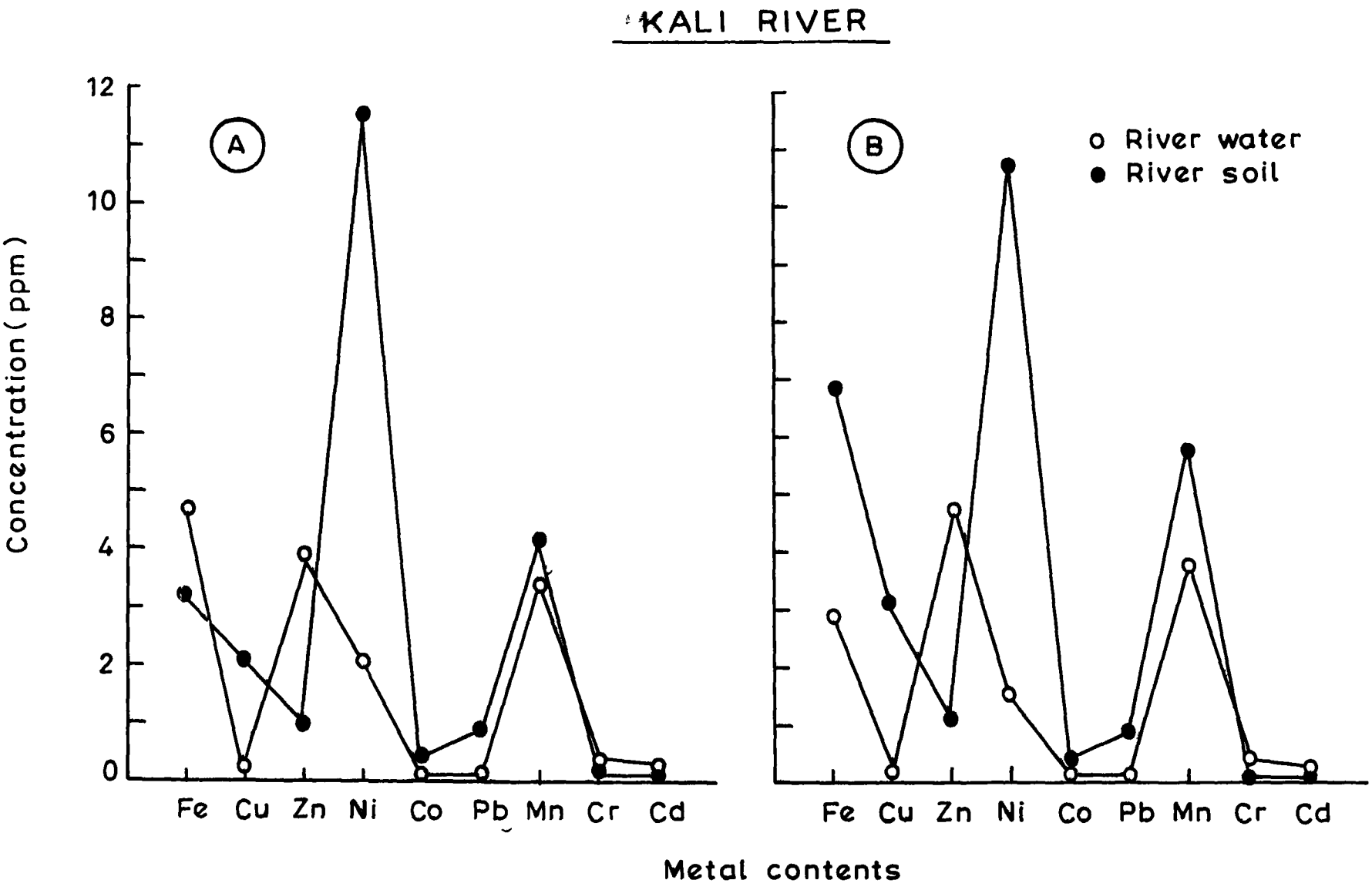

KALI RIVER
A
B
o River water
● River soil
Concentration (ppm)
12
10
8
6
4
2
0
Fe Cu Zn Ni Co Pb Mn Cr Cd
Fe Cu Zn Ni Co Pb Mn Cr Cd
Metal contents

FIG. 59

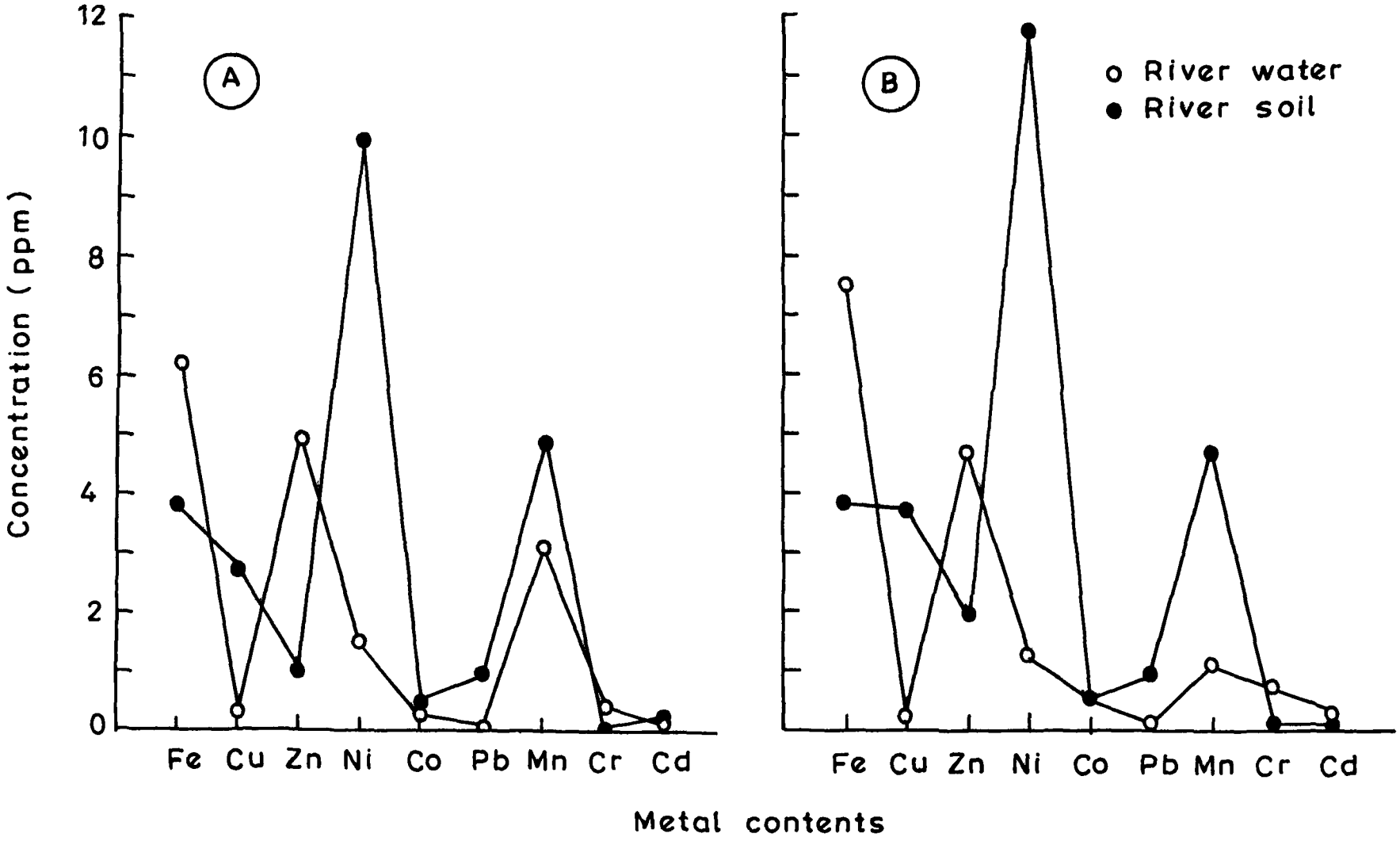

GANGA RIVER
A
B
o River water
● River soil
Concentration (ppm)
12
10
8
6
4
2
0
Fe Cu Zn Ni Co Pb Mn Cr Cd
Fe Cu Zn Ni Co Pb Mn Cr Cd
Metal contents

FIG. 60

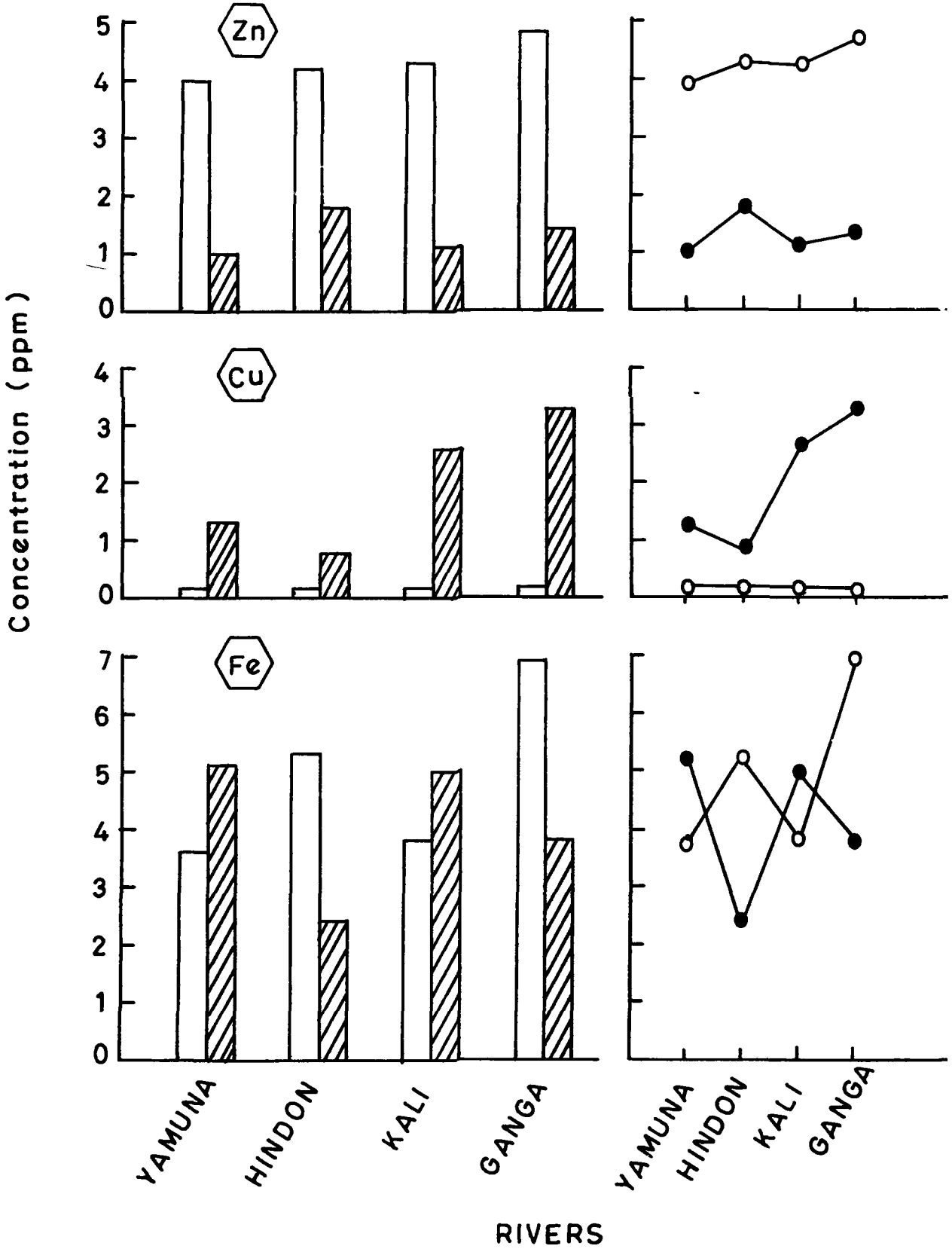


FIG. 61

FIG. 61 – 63 Showing total average concentration of trace metals in Yamuna, Hindon, Kali and Ganga river water and associated soil

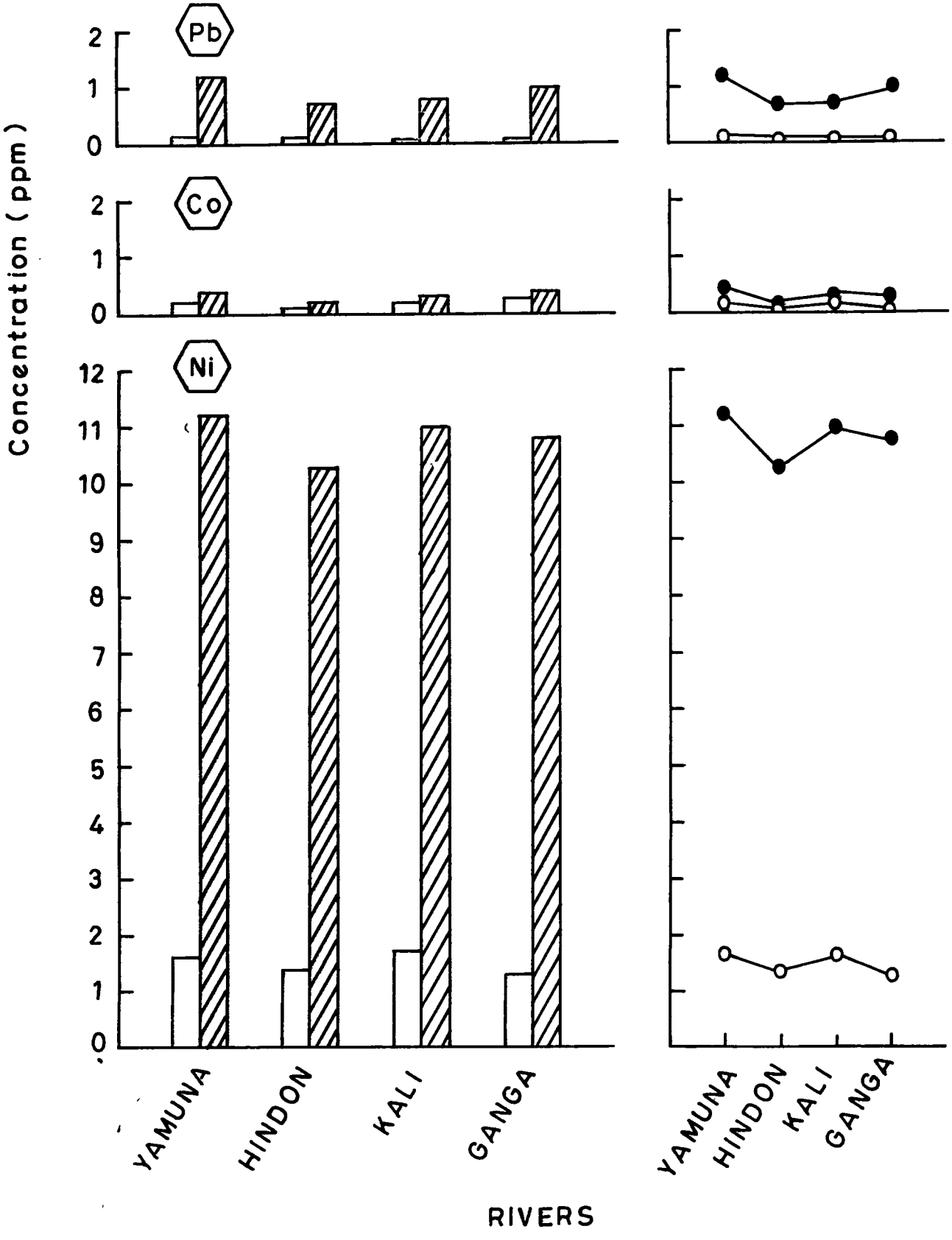

Concentration (ppm)
Pb
Co
Ni
2
1
0
12
11
10
9
8
7
6
5
4
3
2
1
0
YAMUNA
HINDON
KALI
GANGA
RIVERS

FIG. 62

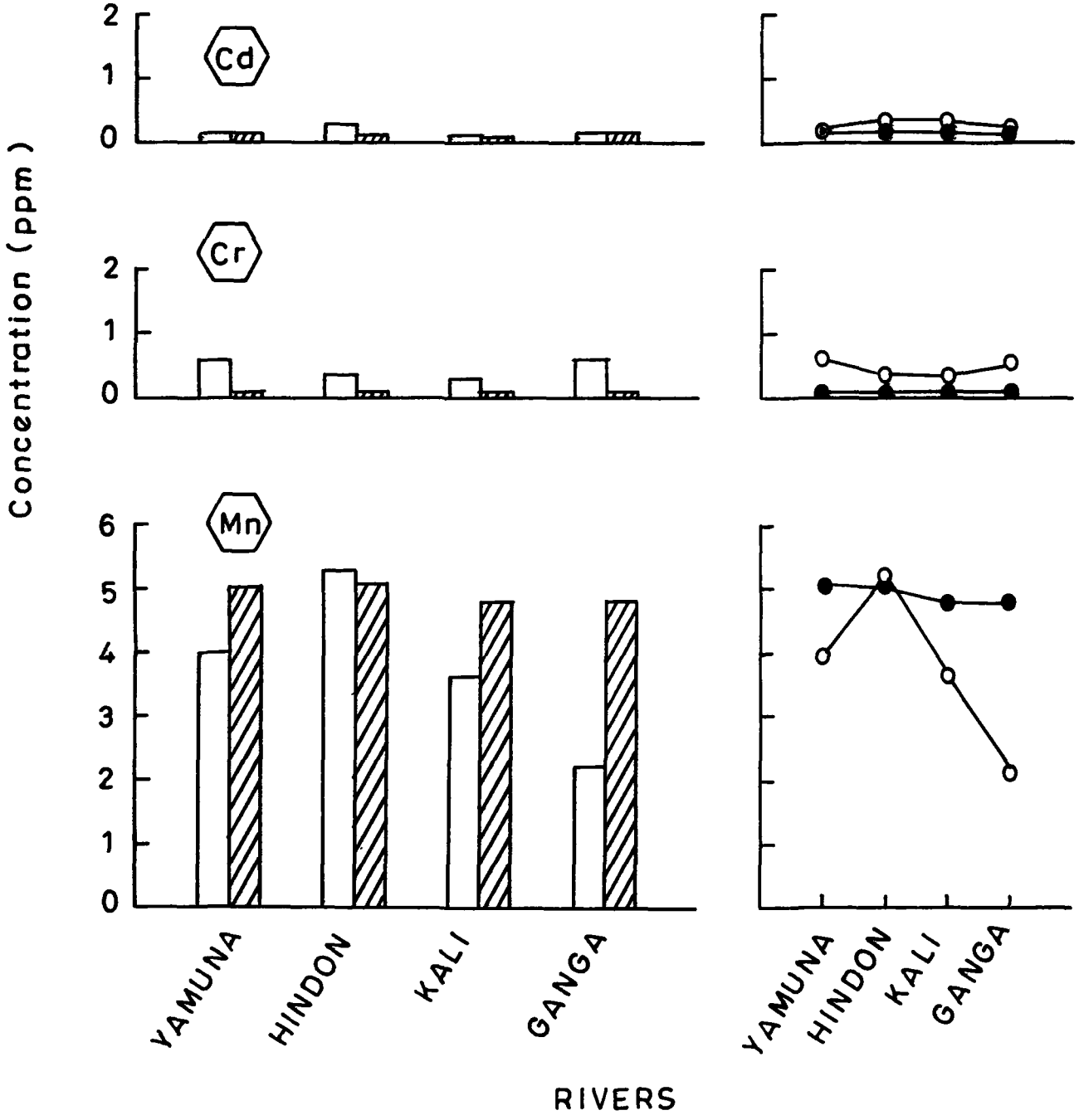

Concentration (ppm)
Cd
Cr
Mn
2
1
0
6
5
4
3
YAMUNA
HINDON
KALI
GANGA
RIVERS

FIG. 63

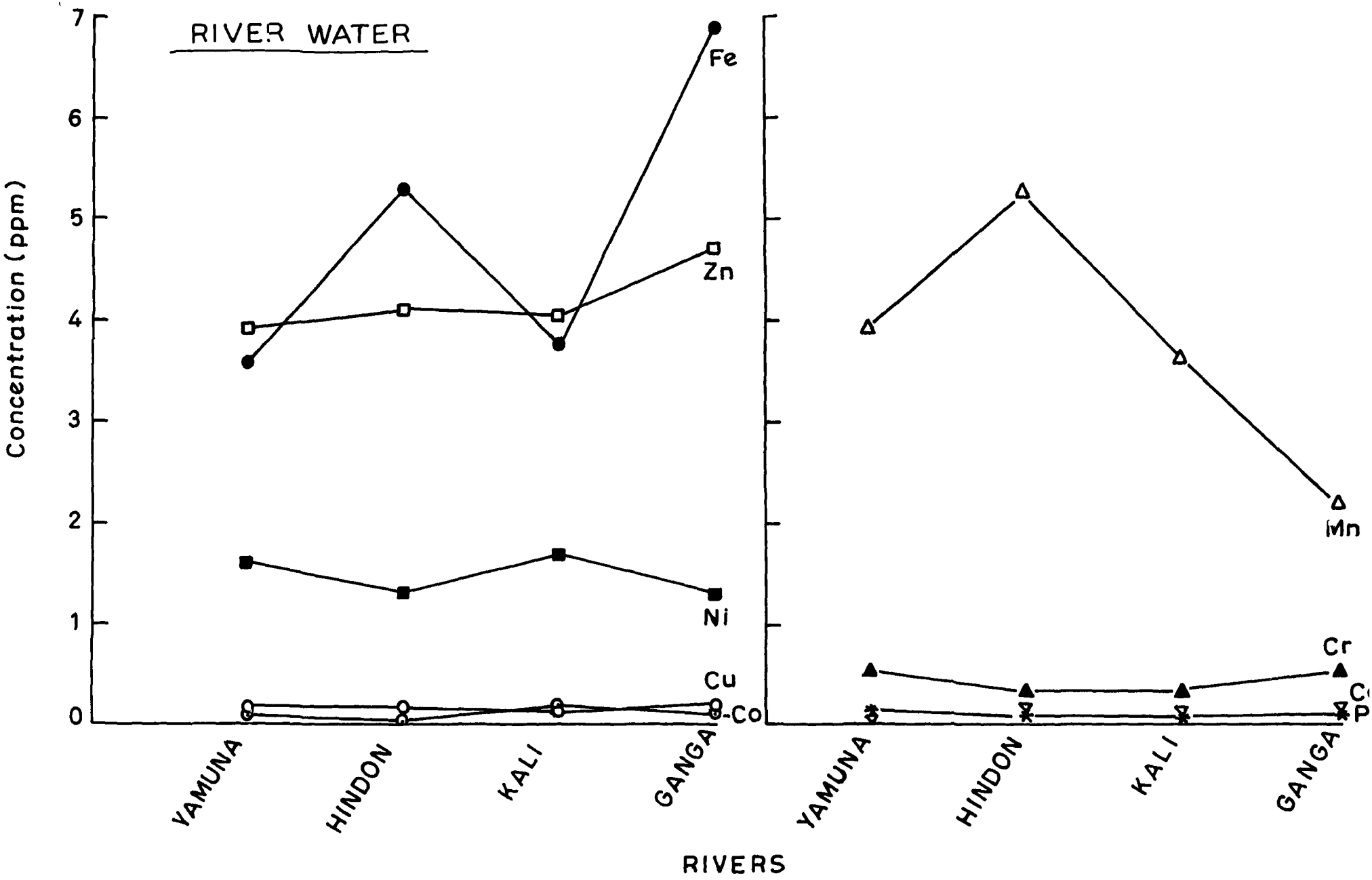


FIG. 64 Showing variation of total average concentration of trace metals in river wate

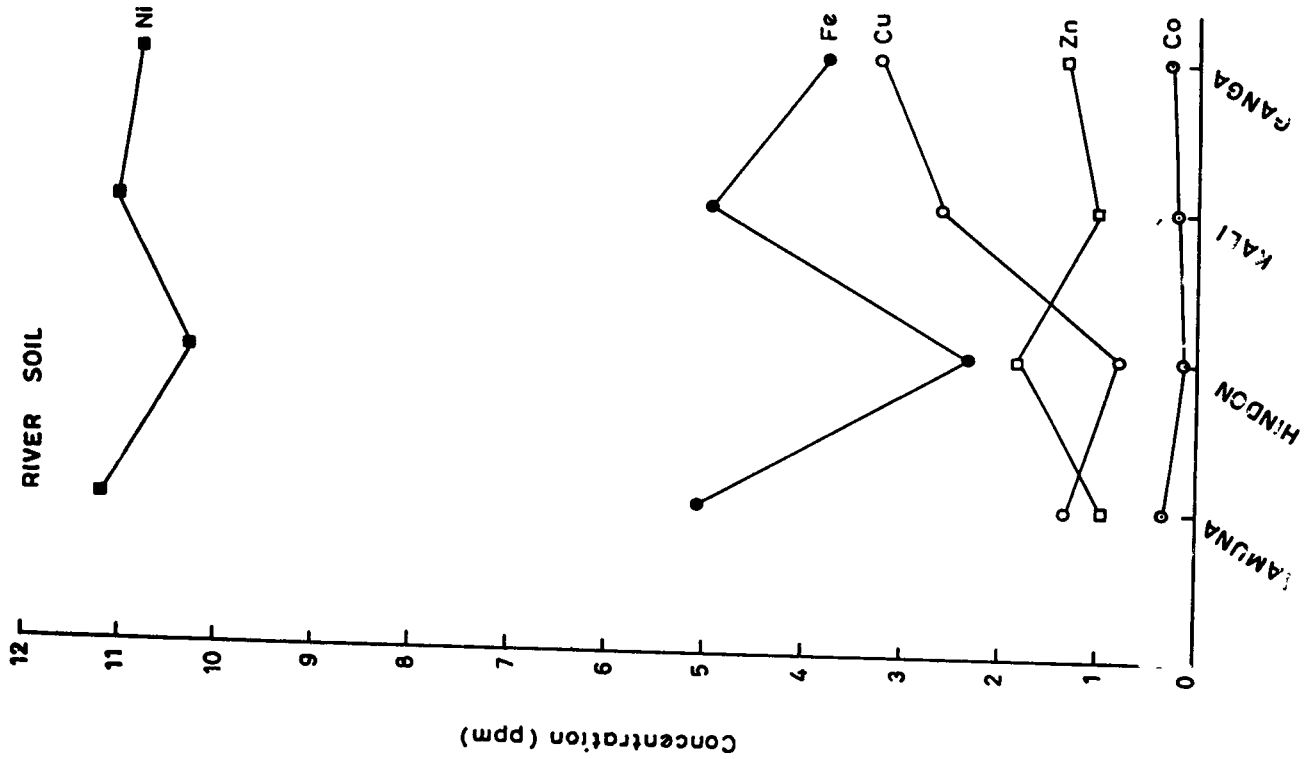


FIG. 65

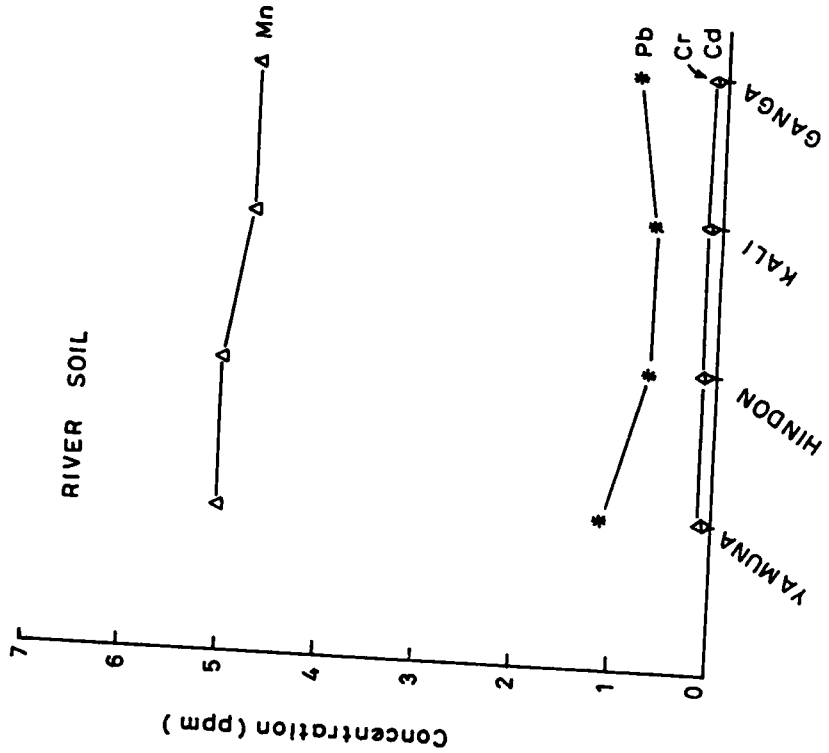


FIG. 65 Showing variation of total average concentration of trace metals in river soils

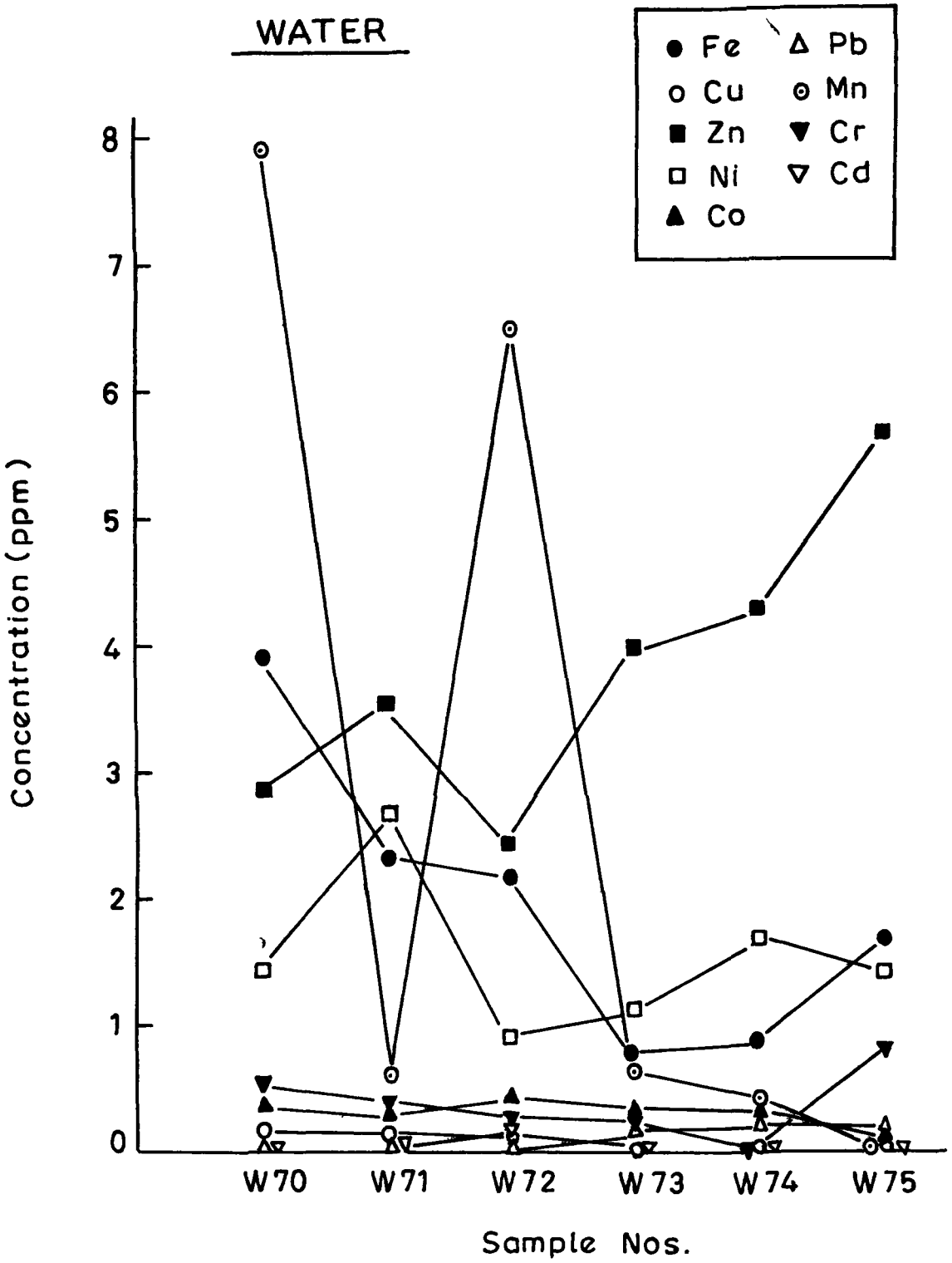


FIG. 66 Variation of trace metal contents in ground-water samples

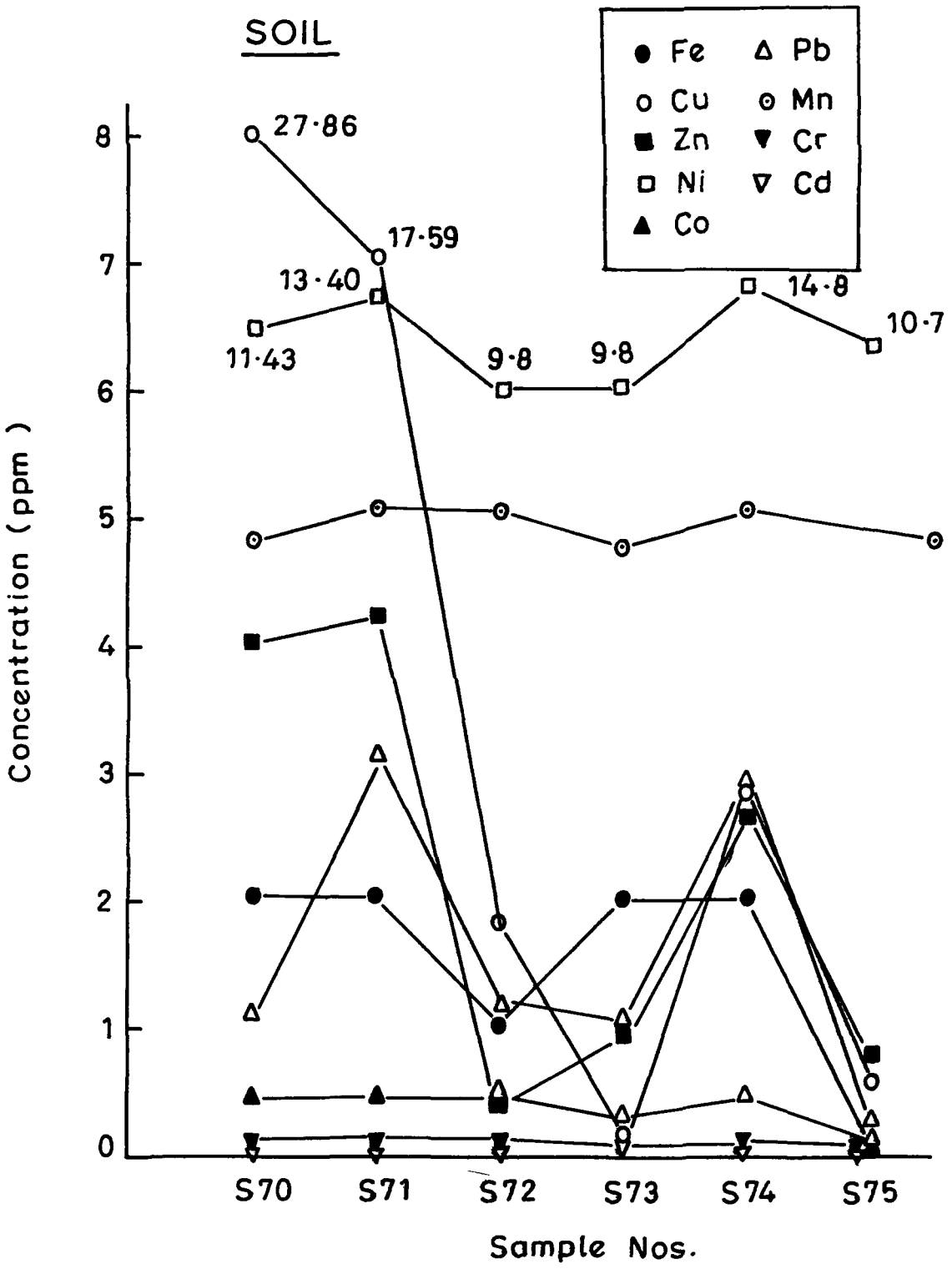


FIG. 67 Variation of trace metal contents in associated soil samples

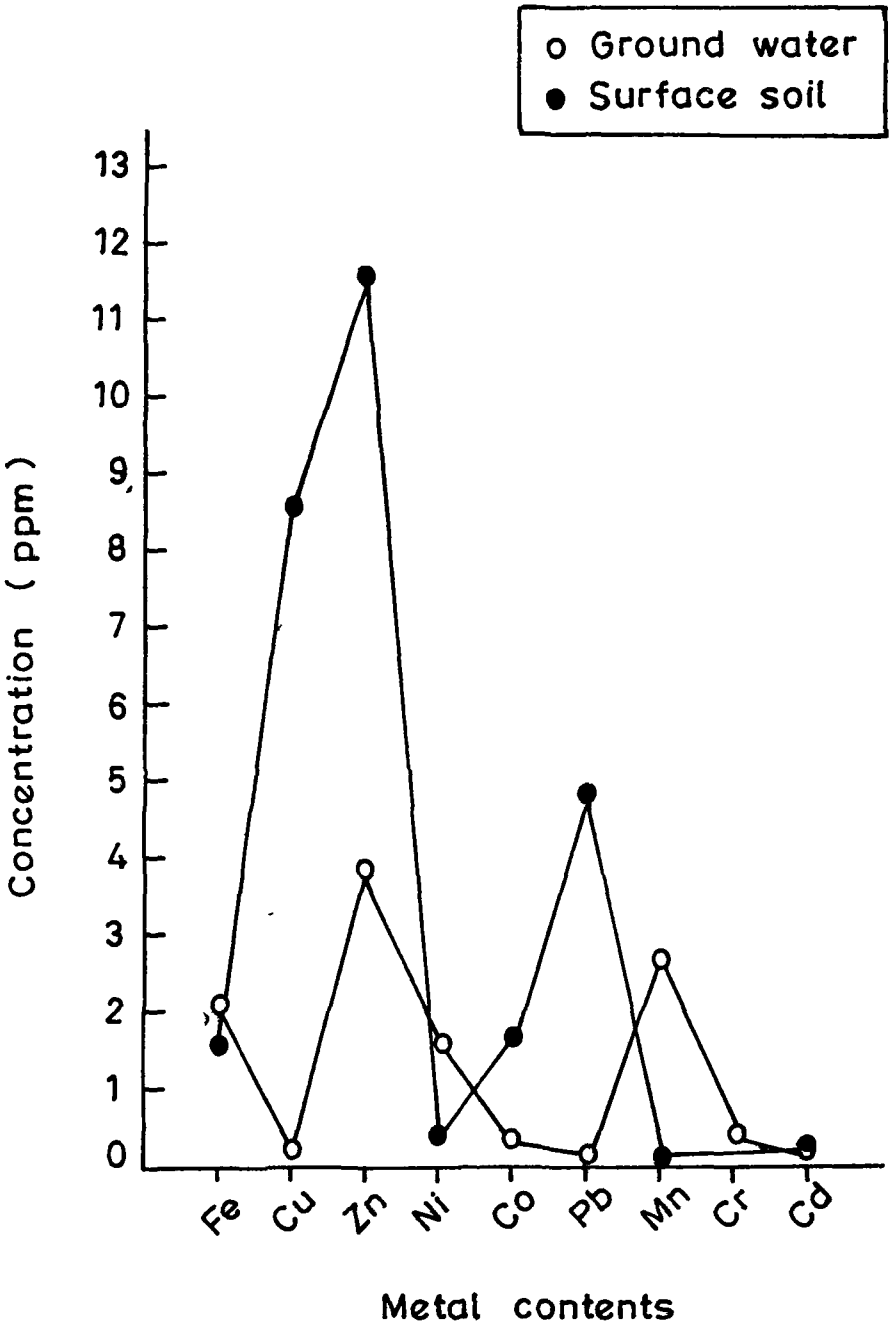


FIG. 68 Showing relationship of average trace metal contents in ground - water and soil sediment